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Model-Based Enterprise Summit Report

by Joshua Lubell, Simon P. Frechette, Robert R. Lipman,
Frederick M. Proctor, John A. Horst, Mark Carlisle, and Paul J. Huang

ARL-RP-466 **February 2014**

**A reprint from *National Institute of Standards and Technology*,
NIST Technical Note 1820, November 2013.**

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Abstract

This report summarizes the presentations, discussions, and recommendations from the Model-Based Enterprise Summit held at the National Institute of Standards and Technology in December of 2012. The purpose of the Summit was to identify challenges, research, implementation issues, and lessons learned in manufacturing and quality assurance where a digital three-dimensional (3D) model serves as the authoritative information source for all activities in a product's lifecycle. The report includes an overview of model-based engineering, technical challenges, summaries of the presentations given at the workshop, and conclusions that emerged from the presentations and discussions.

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Keywords

Model-based, manufacturing, quality, inspection, scanning, MBE, MBD, technical data package, digital thread

Acronyms

AMT Association for Manufacturing Technology

ASME American Society of Mechanical Engineers

ASTM American Society for Testing and Materials

CAD Computer Aided Drawing

CAE Computer Aided Engineering

CAM Computer Aided Manufacturing

CMM Coordinate Measurement Machine

CNC Computer Numerical Control

CSI Customer-Supplier Interoperability

DARPA Defense Advanced Projects Research Agency

DoD Department of Defense

DLA Defense Logistics Agency

DMSC Dimensional Measurement Standards Consortium

EL Engineering Laboratory

FAI First Article Inspection

FEA Finite Element Analysis

GD&T Geometric Dimensioning and Tolerancing

IBIF Industrial Base Innovation Fund

ISO International Organization for Standardization

LOTAR Long-Term Archiving and Retrieval

ManTech Manufacturing Technology

MBD Model-Based Definition

MBE Model-Based Enterprise/Engineering

MEP Manufacturing Extension Partnership

NASA National Aeronautics and Space Administration

NC Numerical Control

NIST National Institute of Standards and Technology

OEM Original Equipment Manufacturer

OSD Office of the Secretary of Defense

PDPMI Product Data with PMI

PLM Product Lifecycle Management

PMI Product Manufacturing Information

PRC Product Representation Compact

PREVIEW Predictive Environment for Visualization of Electromechanical Virtual Validation

QC/QA Quality Control / Quality Assurance

QIF Quality Information Framework

SE Systems Engineering

SME Small or Medium Enterprise

STEP Standard for the Exchange of Product Model Data

SysML Systems Modeling Language

TDP Technical Data Package

1 Overview

The National Institute of Standards and Technology (NIST) Engineering Laboratory (EL) and the Office of the Secretary of Defense (OSD) hosted the fourth in a series of annual Model-Based Enterprise (MBE) Summits on December 11 -13, 2012, at NIST in Gaithersburg, Maryland. Over 170 participants from industry and government met to share the latest technological developments and best practices for MBE. Table 1 lists the organizations that were represented at the 2012 Summit.

Table 1. Organizations Participating in the Summit

3D PDF Consortium	ICF International	Purdue University
3D-Via	Imagecom	Raytheon Company
ACI Technology	Imaginistics	RECON Services/Army
Action Engineering	Integrated Manufacturing Technology Initiative	Rensselear Polytechnic Institute
Aerospace Industries Association	ITI TranscenData	Sandia National Laboratories
Anark Corporation	ITT-Exelis	Siemens Energy Systems
BAE Systems	Jacobs Engineering	Siemens PLM Software
BE Aerospace	Jotne North America.	SolidWorks
Bell Helicopter Textron	L-3 Combat Propulsion Systems	STEP Tools
Boeing Company	Lattice Technology	South Carolina Research Authority
Booze Allen Hamilton	LMI Government Consulting	Subsystems Technologies
Capvidia	Lockheed Martin	Tech Soft 3D
Cost Vision	Lucrum Group	Tetra 4D
CT Core Technologies	M-7 Technologies	Trimech Solutions
Cubic Defense Applications	Marel	TSR Optima
Dassault Systèmes	Metrosage	U.S. Air Force
Decision / Analysis Partners	MFG.com	U.S. Air Force Research Laboratory
Defense Advanced Research Projects Agency	Milltronics Manufacturing	U.S. Research, Development, and Army Engineering Command
Defense Logistics Agency	Mitutoyo America Corporation	U.S. Army Tank Armament Research Development and Engineering Center

Delcam	National Aeronautics and Space Administration	U.S. Coast Guard
Department of Energy	National Institute of Standards and Technology	U.S. Marine Corps
EOS Software	Nextec Applications	U.S. Naval Air Systems Command
Exelis	Northrop Grumman	U.S. Naval Sea Systems Command
GE Aviation	Office of the Secretary of Defense: Manufacturing Technology	University of Iowa
GE Global Research	Oracle	UTRS.
General Dynamics	PAS Technology	Verisurf
George Mason University	Pratt & Whitney	
Honeywell	PTC	

The purpose of the Summit was to identify challenges, research, implementation issues, and lessons learned in manufacturing, quality assurance, and system acquisition where a digital three-dimensional (3D) model serves as the authoritative information source for all activities in the product lifecycle. The 2012 Summit was organized around four model-based technical thrusts:

- Acquisition – including a Special Session on Lightweight Viewers
- Manufacturing – including a Special Session on Manufacturing Process Data
- Inspection
- Systems Engineering (SE)

The Summit also included demonstrations of manufacturing software applications and optical scanning for inspection. This report collects and summarizes information presented at the Summit. Section 2 describes the importance of digital manufacturing for increased productivity and agility. Section 3 highlights the role and importance of standards. Section 4 summarizes each of the technical presentations. Conclusions and recommendations are in Section 5. The appendix contains the summit agenda and all presentation slides approved for public distribution.

2 Manufacturing Goes Digital

The key to success in manufacturing today is the ability to adapt. Constant change has become the norm. Manufacturers must implement new solutions that allow them to respond quickly to customer demands and competition. Several factors are contributing to the need to be agile:

- Development time is getting shorter.
- Manufacturing costs are rising due to increasing demand for raw materials and energy.
- Globalization is increasing competition.
- The demand for custom-configured products is growing.

Digital manufacturing evolved from the need to optimize designs for manufacturing, to decrease the time required to go from design to first production, and to reduce expensive downstream changes. We characterize digital manufacturing as follows:

- It is information-based, enabling rapid design-to-production and dynamic, distributed production systems.
- It depends on virtual process modeling, systems integration, simulation analysis, data analytics, and data validation capabilities.
- It requires integrated engineering software systems comprising 3D computer-aided design (CAD), simulation, analysis, computer-aided manufacturing (CAM), and various collaboration mechanisms to create manufacturing process plans.
- It is a key point of integration, enabling the exchange of product-related information between design and manufacturing groups within an enterprise.

Digital manufacturing led to the creation of the "digital thread" – extending the digital integration of design and production throughout the entire product lifecycle. The digital thread connects conceptual design, requirements, analysis, detail design, manufacturing, inspection, operations, refit, and retirement. The finished assembly can be traced back to the original requirements and design model. The unbroken data link through the lifecycle is the digital thread.

The digital thread helps transform rigid supply chains into dynamic production systems by making data directly available to all the actors in the system. A dynamic production system is a fully-integrated, collaborative manufacturing system that responds in real time to changing demands and conditions in the factory and in the supply network. The primary characteristic of a dynamic production system is the ability to easily and rapidly reconfigure factory production and supply networks to optimize system performance. Such systems deal effectively with uncertainty and abnormal events, and learn from past experience to enable continuous improvement. They provide seamless interoperability between factory processes and supply networks, and between large manufacturers and small manufacturers.

With a valid digital thread, suppliers can trust that data will work in their manufacturing processes. When design changes come through the supply network, the information is immediately available to suppliers in a physics-based exact model. Digital processes eliminate transfer time and data validation time. Differences between drawings require human interpretation. Differences between digital models are flagged automatically.

Another benefit of the digital thread is that it reduces the use of special-made physical (hard) tooling for system assembly. Particularly sensitive or critical subassemblies have to come together in exact true positioning at tolerances that require expensive, custom hard tooling to verify correct alignment. Manufacturers can reduce physical tooling requirements by using optical tooling and digital datums in the assembly model. A digital datum is a mathematical reference from which measurements can be taken, such as the axis of a hole or a plane that lies on a mating surface. Laser alignment, production processes, and automated assembly processes trace back to the assembly model through the digital thread. The use of optical measurement devices rather than physical tooling to establish measurement references eliminates the cost, maintenance, and storing and moving of dedicated hardware over the production life.

3 The Role of Standards in Digital Manufacturing

Standards-based exchange of product data has been very successful [1], with widespread commercial support of formats like ISO 10303 (also known as STEP, the *Standard for the Exchange of Product Model Data*) [2], ISO 14306 (also known as JT) [3], and ISO 14739 (also known as 3D-PDF) [4]. The exchange of manufacturing process data, however, has had minimal success. Despite the benefits of being able to exchange process data, the idea is controversial for several reasons:

- Manufacturing processes are often highly customized to fit in-house production capabilities, types of machines and processes, tooling, fixturing, and rules, guidelines, and conventions. The associated manufacturing data would be useless to anyone other than the original manufacturer.
- Process descriptions are considered proprietary information by most manufacturers. Making process descriptions available to customers, who could in turn distribute the information to competitors, would diminish the original manufacturer's competitive edge. Even if manufacturing data were available to customer facilities or third parties, the engineers or machinists would choose to re-create the processes from the original design requirements, to have confidence in the resulting product.
- There are few neutral formats for manufacturing process data, and native formats are so specific to particular machines that there is little chance for portability. The most prevalent data format, numerical control (NC) code for machine tools, is nominally standardized as ISO 6983 [5], but the variation in dialects and customization for machine options makes it almost impossible to share. Indeed, even understanding NC code in the absence of the original programming system is a forensic exercise.

However, there are compelling business drivers for standardizing the exchange of manufacturing process data:

- Within a large or global company's manufacturing facility, high-level "macro" process plans can be defined by one facility, and sent to other facilities for refinement into "micro" process plans suitable for the actual tooling and fixturing available. Much of the work needed to translate design requirements into manufacturing features and operations could be done once, and shared.
- Nominal manufacturing data for a baseline process could be included with design data when soliciting bids from suppliers. This would save the suppliers the time and effort to develop a candidate process needed to determine cost and lead time estimates.
- Well-developed manufacturing processes could be sent out to the local supply chain for quick response when surges in need arise (the "Kinkos" model, where production is outsourced to a third party).
- Manufacturing data can be used to drive simulation and training, reducing the time needed to recreate manufacturing processes on similar equipment.

- Manufacturing data standards are essential for long-term sustainment of complex products with a decades-long service life such as aircraft and military hardware. Without standards, even if a government or private sector procurer were able to obtain proprietary process information from the manufacturer at the time of purchase and validate that the information is correct and complete, there is little assurance that this information will be usable throughout the entire product lifecycle as process technologies and manufacturing software change.
- Critical manufacturing processes, where the process is the only known way to produce something [6], have become increasingly commonplace as more specialized and proprietary technologies continue to be developed. Not having a standard for representing information for a critical manufacturing process increases the risk of losing the capability to refabricate, disassemble, repair, or inspect an item produced using the process.

Standards, such as ISO 10303-238 (STEP-NC) [7], have been used to successfully exchange part programs for machining. Other recently developed standards cover auxiliary data needed to fully describe manufacturing. These include ISO 13399 [8] for cutting tool data representation and exchange, and the draft ASME B5-59 standard [9] for representing machine tool capabilities and performance. More recently, ISO/DIS 10303-242 [10] (also known as STEP AP242) enables the representation of semantic manufacturing and assembly information, such as assembly tolerances, surface finish, and manufacturing process information. Together, these standards can be used to much more fully automate the job of preparing manufacturing processes from design requirements, and sharing those processes throughout a model-based enterprise.

4 Presentation Summaries

This section provides summaries of the presentations, grouped by technical thrust. Subsection titles are presentation titles. Italicized text following the subsection title identifies the presenter and organization represented. Summary text for the most part paraphrases the actual ideas communicated by the presenter. An exception is Jim Osterloh's summary (4.3.1, second paragraph), where we describe a real-time demonstration.

4.1 Model-Based Acquisition

A military acquisition strategy must be based on centralized policies and principles, yet must also allow for decentralized and streamlined execution of acquisition activities. Such an approach provides agility and encourages innovation, without sacrificing discipline and accountability [11]. This subsection summarizes the presentations discussing model-based approaches to meeting acquisition challenges. Many of the presentations focus on the Technical Data Package (TDP), a collection of all product data needed to manufacture and maintain the product. The MIL-STD-31000 standard [6] specifies TDP requirements, and was recently updated to support 3D model-based, digital TDPs.

4.1.1 DoD Modeling and Simulation Support to Acquisition

Philomena Zimmerman, Office of the Deputy Assistant Secretary of Defense for Systems Engineering, System Analysis

Modeling and simulation are key enabling tools for SE support to all phases of acquisition. Fundamental aspects of application of modeling and simulation have been documented for program support. These aspects underpin changes and assessments in both SE guidance and in application to program support. System modeling is expected to become a more prominent aspect of the modeling and simulation landscape and will be a key aspect of future initiatives, such as Engineering Resilient Systems.

4.1.2 A-10 Pilot Program Overview "DLA Engages Model-Based Enterprise"

Ric Norton, Defense Logistics Agency

The A-10 wing replacement program is the first large-scale provisioning effort for a major weapons system platform that uses the 3D model as the master reference (rather than a 2D drawing) for the TDP deliverable. The supply chain user community is working with a 3D PDF derivative rather than STEP or native CAD file to perform specific logistics activities, such as cataloging. DLA Logistics Information Service has completed their preliminary review of the A-10 wing provisioning parts lists using the 3D PDF TDPs. Updates and resulting comments were provided to the Air Force customer.

4.1.3 Contracting for Technical Data Packages within a Model-Based Enterprise

Ric Norton, Defense Logistics Agency

This DLA project identifies how the government currently drives TDP contract deliverables within an MBE environment. Gap and trend analyses will highlight current policy, procedure, directives, standards, systems and contract language used to drive 3D model data requirements and exchange. A business case will suggest a path forward to better satisfy model data requirements in a contract. The research compiled in this project will be a valuable source of information for those engaged in future MBE Concept of Operations development.

4.1.4 Technical Data Package Lifecycle Management

Howard Owens and Brent Gordon, Naval Air Systems Command

At the Naval Air Systems Command, there are many issues and risks related to TDP lifecycle management. Those risks take place during the acquisition, quality assurance, storage, translation, and use stages. For quality assurance, there are no standardized 3D model acceptance criteria. For translations between multiple CAD systems, there are no standardized 3D model validation criteria. Model defects are not recognized until the model is used. Models do not often match the Original Equipment Manufacturer (OEM) "As-Built" or "As-Delivered" manufactured part. The evolution of technology has enabled programs to leverage 3D models in acquisition. However, those advances have outpaced policies, processes, tools, and infrastructure.

There is a need to transition from non-integrated development environments to interoperable Product Lifecycle Management (PLM). PLM is the relational environment that ties all of the program data to the assembly structure and vice versa. Current initiatives supporting interoperable PLM include (1) the OSD /DoD Engineering Drawing & Modeling Working Group and (2) the Optical Generation of 3D Models for Computer Aided Manufacturing pilot project through OSD with the National Center for Manufacturing Sciences. The pilot project scope includes 3D model-based scanning and inspection.

4.1.5 Special Session: Lightweight Viewers

Lightweight viewers are software applications offering a low-cost way for humans to view and potentially for applications to consume geometry and Product Manufacturing Information (PMI). These viewers are helpful for implementing TDPs and enable collaboration without requiring that business partners buy expensive CAD systems. This subsection summarizes presentations discussing several data formats implemented in current lightweight viewers.

4.1.5.1 Effective MBE Using 3DPDF and 3D HTML

Chris Garcia and Paul Perreault, Anark

3D PDF and 3D HTML viewers are both well suited for 3D MBE deployment. 3D HTML provides maximum flexibility and is the preferred approach when deployed inside a corporate firewall. 3D PDF is best for use cases requiring communication with external suppliers, customers, and collaborators outside a corporate firewall. Unlike proprietary CAD viewers, 3D PDF and 3D HTML viewers are based on open formats and are deployable on most computers without the need for special downloads or browser plug-ins.

4.1.5.2 3D PDF Overview

David Opsahl, 3D PDF Consortium

The three principal activities involving Model-Based Definition (MBD) data are exchange, visualization, and communication. Communication differs from visualization in that it conveys additional information such as precise geometry and supporting documentation. Product Representation Compact (PRC) [4], a content standard for 3D PDF, supports not only visualization, but also communication. PRC originated as an Adobe specification and is now undergoing standardization in Subcommittee 2 (Application issues) of ISO Technical Committee 171 (Document management applications). Commercial software tools are available that can validate whether a 3D PDF document correctly represents the information in an authoritative model. Although websites and HTML-based technologies can also support exchange, visualization, and communication of MBD data, 3D PDF documents are better suited for offline access, long-term archiving, and as deliverables to regulators and compliance authorities.

4.1.5.3 JT Overview

Dennis Keating, Siemens

JT is a 3D data format developed by Siemens PLM Software and is used for visualization, collaboration, and CAD data exchange. It can contain any combination of approximate (faceted) data, boundary representation surfaces, PMI, and model metadata (attributes). JT can be exported from a native CAD system, and information can be inserted into a JT file by other systems such as Product Data Management systems.

Open JT is a free standard subset version of JT. The JT Open program is a community of software vendors, users, and interested parties that share JT knowledge and influence the direction of JT technology. The goal is to encourage widespread adoption of JT for 3D visualization, collaboration, interoperability, and data archiving. Open JT has been established as an ISO standard. There is a no-cost viewer, published file format (free to download), and developer toolkit available through the JT Open program.

4.1.5.4 Creo View

Madhavi Ramesh, PTC

PTC is moving to complete 3D workflow in its product lifecycle applications because drawings are not well suited for wide-spread collaboration across geographical barriers and because 2D drawings are more prone to errors than 3D models. An Aberdeen study found that 30% - 40% of part non-conformances are due to inaccuracies and interpretation errors using 2D drawings [12]. Creo View provides interactive viewing of 3D information and is integrated with PTC's Windchill product data management system and Arbortext technical publishing engine. Creo View provides application programmer interfaces for Java, web applications, and Microsoft Office. Built-in scalability allows for very large datasets. Creo View also provides remote data access through mobile and cloud applications.

4.1.5.5 Lightweight Graphics

Garth Coleman, 3DVIA

The 3DVIA mission is to empower anyone, at any skill level, to create and share professional quality 3D content and experiences through highly interactive software applications. Effective communication requires much more than a simple presentation. It requires a new way of connecting with your audience: one that is effective, engaging, and real. 3DVIA leverages 3D CAD and the 3DEXPERIENCE Platform from Dassault Systèmes with a suite of authoring and publishing applications for desktop, cloud, and mobile delivery. Virtual training is one notable area of application for 3DVIA lightweight graphics visualization, communication, and experience technology.

4.2 Model-Based Manufacturing

This subsection summarizes presentations focusing on the use of 3D digital models to drive process planning and manufacturing applications. Included in this subsection is the summary of a special session on manufacturing process data.

4.2.1 GE Model-Based Manufacturing

Dean Robinson, GE Global Research

GE defines model-based manufacturing as the integration of digital design information with manufacturing process models. The goals of model-based manufacturing at GE include design and manufacturing cycle time reduction, manufacturing process yield and quality improvement, and product/component cost reduction. Key challenges include the introduction of new materials, material systems, and manufacturing processes such as additive manufacturing. GE's model-based manufacturing laboratory is working not only in manufacturing and inspection, but also in design for manufacturing, and tolerance modeling. GE reduced their tooling design time 75% by using model-based methods.

GE is using model-based methods to enable adaptive manufacturing for repair of expensive components. GE's Intelligent Turbine Airfoil Manufacturing will make use of the "industrial internet" for tying information together, resulting in better decisions. GE is focusing on data quality for in-process models to maintain consistency between in-process models and the master model. Model edits in downstream processes such as computer aided manufacturing (CAM) break the link to the engineering design model. GE is working to use MBE and process knowledge to maintain design intent, improve quality, yield, and productivity. Most manufacturers need more modeling and simulation to optimize processes. There is too much overhead with starting from scratch in each different simulation/modeling system. We need to be able to bring models into these systems automatically.

4.2.2 MEP: Connecting and Assisting U.S. Manufacturers with MBE Approaches to Defense Business Opportunities

David Stieren, Manufacturing Extension Partnership, NIST

The NIST Manufacturing Extension Partnership (MEP) program mission is to promote business growth and connect manufacturers to public and private resources essential for increased competitiveness and profitability. There are over sixty MEP centers with nearly 400 field locations throughout the United States. MEP serves over 30,000 manufacturers and conducts more than 10,000 projects annually. According to client data reported in 2011, aggregate MEP impacts include $8.2B increased/retained sales; $1.9B new client investment, $1.3B cost savings, and 60,497 jobs created or retained.

MEP has several ongoing initiatives with the goal of improving manufacturers' profitability. One area of emphasis is providing support for implementing advanced engineering practices and integrating engineering with production and other manufacturing execution functions. This includes working with DoD to implement MBE approaches throughout the supply base. NIST MEP is working with the Army Research Laboratory, BAE Systems, and the MEP centers to transition the DoD supply base to MBE. A 2009 MBE Supplier Capability Assessment reported that two-thirds of participating suppliers are ready to operate in a model-based environment.

U.S. manufacturers are looking for specific MBE requirements and implementation guidance from DoD. Preliminary toolsets developed by DoD Manufacturing Technology (ManTech) have been well received by the industrial community. MEP assessed 3D TDP software tools and data formats in 2012. A survey of manufacturers in the Army supply chain indicated a strong preference for 3D TDPs over 2D drawings. A large majority said they plan to use 3D TDPs in their CAM processes.

4.2.3 Customer - Supplier Interoperability (CSI) Program

John Gray, ITI TranscenData

The CSI program was sponsored by DoD and the U.S. Air Force Research Laboratory to develop software solutions addressing engineering inefficiencies associated with data exchange and to accelerate the adoption of a Model-based Enterprise (MBE) in defense supply chains.

The CSI project focused on the problem of sharing system information during the collaborative phase of design. Challenges included:

- Supporting differing data requirements across contracts, including submittals in standards-based and native CAD formats
- Supporting versions and model manipulation rules
- Enabling companies to support very complex requirements based on the depth and complexity of the supply chain and the product
- Minimizing the investment that companies make to manually convert the data or to install, maintain and train engineers on the systems and data requirements

The CSI solution provides automation that eliminates the manual effort required to support variations in data submittal requirements. Workflows include execution of software in a specified sequence based on specified translation paths. Workflows can dynamically change to improve the conversion results. The benefits of the CSI project include cost reduction in the upfront design phases when collaboration requirements drive data sharing on a day-to-day basis, and reduced time-to-market by eliminating delays in manual preparation of manufacturing data for sharing and delivery. The CSI solution will tackle the highest cost elements of interoperability in the context of collaborative design, TDPs, “design to” packages, and “build to” packages. Through the automation of manual tasks, CAD validation, and advanced toolsets, the CSI program developed an interoperability framework for the defense industrial base. Using side-by-side comparisons with current best practices, CSI technologies will generate projected cost savings of approximately $50M per year when fully adopted by all supply chain members in a large defense acquisition program.

4.2.4 Enabling the Digital Thread

Karen Kontos, Honeywell

MBE at Honeywell is driven by complexity of products and communication of design intent. Design collaboration occurs across hundreds of design communities (internal and external). Honeywell acts as the design integrator of complex cyber-physical (mechanical and electrical) assemblies. Honeywell’s MBE architecture must take into account the following factors:

- Complexity of the aerospace supply chain
- Complexity of products

- Product lifecycle support – long-lifecycle services are a large portion of Honeywell's business
- Demands for re-use
- Outsourced manufacturing for more than 50% of Honeywell's products

Communication and exchange processes associated with digital data must become more efficient and robust to support a sustainable business. "Model is the master" is a fundamental enabler for tracing design intent, streamlining inspection process development time, reducing errors in design and manufacturing through early identification of manufacturing issues, and eliminating redundant efforts to re-create information. MBE also supports early analysis of manufacturing cost during design phase, and design for manufacturability.

Honeywell achieved the following MBE milestones in 2012:

- Formally established an MBE organization as a part of product lifecycle management/engineering operations in Honeywell Aerospace
- Started internal MBE/TDP initiatives
- Completed (with ITI TranscenData – see 4.2.3) the CSI project
- Completed TDP and manufacturing pilot projects

Honeywell's external industry initiatives and standards support includes the DoD MIL-STD 31000 TDP specification, participation in PDES, Inc., STEP AP242 development, and participation in the Aerospace Industries Association Long Term Archiving and Retrieval (LOTAR) standards development effort (http://www.lotar-international.org).

4.2.5 PTC's MBE Solution

Madhavi Ramesh, PTC

PTC's solution for MBE uses a digital "master model" (not necessarily CAD) from which all downstream activities can be derived to create the final product. In this context, "design" is merely creating geometry, while "engineering" is the use of physics-based rules to develop new products. The master model contains not only CAD geometry, but also additional information needed for production, assembly, and field support. This additional information could include Geometric Dimensioning and Tolerancing (GD&T), material specifications, bills of material, process specifications, and inspection data.

The MBE approach requires engineers to model and simulate an entire system operating in its setting to fully understand the system's behavior. An advantage to this approach is that integrating engineering-design models within a model-based environment helps pinpoint design-performance problems as they arise.

4.2.6 DARPA Open Manufacturing

Mick Maher, Defense Advanced Research Projects Agency (DARPA)

The goal of the DARPA Open Manufacturing program is to lower the cost and speed the delivery of high-quality manufactured goods with predictable performance. The program aims to do so by creating a manufacturing framework that captures factory floor and materials processing variability and integrates probabilistic computational tools, informatics systems, and rapid qualification approaches. Target applications will include metals additive manufacturing and the manufacturing of bonded composites structures.

Driving Open Manufacturing is the need to:

- Maintain legacy systems longer
- Maintain a robust industrial base that is not dependent upon DoD, but can be responsive when called upon
- Increase agility and rapid manufacturing capabilities
- Increase performance while reducing cost and weight
- Build more prototype systems to keep performance innovation alive
- Establish confidence in these new processes – if risks are not known and controlled, non-traditional/innovative processes will not be implemented

The Open Manufacturing Program is developing four primary technologies:

- Probabilistic, physics-based process-property models to predict and guarantee that a manufactured product's range of performance lies within design requirements
- A rapid qualification schema that employs statistical methods and probabilistic simulation tools for low-cost, high-confidence prediction of system performance
- New manufacturing and fabrication processes that result in improved performance, reduced production times, and more affordable manufacturing
- Military-service-affiliated manufacturing demonstration facilities that serve as repositories of focused manufacturing knowledge and infrastructure

4.2.7 Smart Manufacturing Research Programs in the NIST Engineering Laboratory

Simon Frechette, National Institute of Standards and Technology

U.S. manufacturing must adapt to a changing world and more aggressive and adept competition. Innovation, productivity, and quality are critical factors for the success of U.S. manufacturers. NIST's Engineering Laboratory (EL) helps manufacturers to innovate and compete more effectively by providing measurement science to help advance technology and reduce risk. EL manufacturing programs focus on the development of measurement and testing methods, predictive modeling and simulation tools, protocols, and reference artifacts. EL programs

develop the technical basis for manufacturing-related standards and practices. EL manufacturing programs work closely with U.S. industry, industrial consortia, standards development organizations, and academia.

The EL smart manufacturing strategic goal and sustainability strategic goal currently include the following manufacturing programs:

- Smart Manufacturing Processes and Equipment
- Next-Generation Robotics and Automation
- Smart Manufacturing and Construction Systems
- Systems Integration for Manufacturing and Construction Applications
- Sustainable Manufacturing

The Smart Manufacturing Processes and Equipment Program advances measurement science to enable rapid and cost-effective production of innovative, complex products through advanced manufacturing processes and equipment in the following research focus areas: Additive Manufacturing Measurement Standards, Machine Tool Performance, Machining Process Modeling, and Nano Manufacturing Measurement.

The Next Generation Robotics and Automation Program advances measurement science to safely increase the versatility, autonomy, and rapid re-tasking of intelligent robots and automation technologies for smart manufacturing and cyber-physical systems applications in the following research areas: Sensing and Perception Manipulation, Mobility, and Robot Autonomy.

The Smart Manufacturing and Construction Systems Program advances measurement science to enable real-time monitoring, control, and performance optimization of smart manufacturing systems at the factory or site in the following research areas: Factory Networks, Information Modeling & Testing, and Performance Measurement and Optimization.

The Systems Integration for Manufacturing and Construction Applications Program advances measurement science for integration of engineering information systems used in complex manufacturing networks to improve productivity. Research areas include: Engineering Systems Integration, Production Network Integration, and Production Network Data Quality.

The Sustainable Manufacturing Program advances measurement science to achieve sustainability across manufacturing processes, enabling resource efficiency and production network resiliency in two research areas: Sustainable Processes and Resources, and Integration Infrastructure for Sustainable Manufacturing.

4.2.8 The Army's Implementation of a Net-centric Model-based Enterprise

Sanjay Parimi, Armament Research Development and Engineering Center

The major objectives of net-centric MBE are (1) enterprise adoption, (2) deployment of technical and business processes, (3) development and deployment of Product Data Management, and (4)

development of standards-based model-based technologies. Industry assessments we conducted jointly with NIST MEP (see 4.2.2) show widespread acceptance of our 3D TDP approach.

Accomplishments to date include:

- Development and implementation of fully-annotated CAD models
- Establishment of a CAD validation capability
- Creation of a 3D TDP for the M2A1 machine gun's quick change barrel
- Development of animated Digital Work Instructions for fielded systems

Our current activities include:

- Creating and deploying a Service Information System to support logistics operations
- Developing a new version of MIL-STD-31000
- Implementing MBE capabilities at Anniston Army Depot
- Developing an Interactive Electronic Technical Manual for installing the Self-Protection Adaptive Roller Kit, equipment providing pre-detonation of pressure-plated improved explosive devices, and blast dampening for Mine Resistant Ambush Protected and other tactical wheeled vehicles
- Evaluating and implementing reverse engineering technologies

The Accelerated, Adaptive Army Fabrication is a new ManTech-funded project whose output will be a prototype weapon system employing Army-owned design and manufacturing knowledge for next-generation improvement and sustainment. Accomplishments so far include development of software tools to handle requests for quotes, deployment of an MTConnect-enabled [13] platform for inspection data, testing and validation of additive manufacturing equipment, and piloting of machining optimization tools.

4.2.9 PREVIEW

Timothy Marler, University of Iowa, Advanced Manufacturing Technology Group

The Predictive Environment for Visualization of Electromechanical Virtual Validation (PREVIEW) project will demonstrate the utility of providing designers with advanced modeling, simulation, and visualization capabilities to analyze various design alternatives early in the design process. Partners on this project include Rockwell Collins and the South Carolina Research Authority, with funding provided by the Air Force Research Laboratory. PREVIEW uses video game technology to provide physics-based simulation, visualization, testing, and analysis. Future plans include virtual circuit testing, inter-process communication to support people in different locations working on same model at the same time, additional analysis capabilities to reduce requalification costs, and automating a feedback loop from analysis to design.

4.2.10 Implementing Model-only at Cubic Defense Applications

Peter Buzyna, Cubic Defense Applications

Cubic Defense Applications employs model-based technologies including CAD, 3D printing, and 3D scanning. Cubic partnered with Anark to develop a 3D PDF-based publishing tool for a MIL-STD-31000 implementation. The tool can export a PMI-annotated model from SolidWorks to 3D PDF.

4.2.11 Special Session: Manufacturing Process Data

Barriers to incorporating process data into MBE include:

- Lack of trust in process data produced by someone else
- Impact of even minor changes in tooling, setup, or machine tool performance on portability
- Concerns about divulging intellectual property to competitors

On the other hand, there are compelling use cases for process data sharing, including:

- Collaborative process development between experts using different software applications
- Modeling and simulation of manufacturing
- Data interchange between CAM systems
- Long-term preservation of process descriptions and associated tooling, fixturing, and machine tools
- Supply chain management – 3D models plus high-level process plans can be sent to candidate suppliers, or posted to e-bid sites, enabling a quicker and more accurate response
- Optimizing the use of a distributed enterprise's manufacturing resources

Presentations summarized in this session include talks about CAD-to-CAM interoperability and the STEP-NC standard for CAM-to-CAM data exchange, and also talks discussing specific CAM software applications. Also summarized is a panel addressing questions and issues raised by the audience.

4.2.11.1 Overview of Siemens CAM Systems

Sada Reddy, Siemens

The Siemens NX-CAM software application is organized into modules for milling, turning, electrical discharge machining, feature-based machining, motion control, post-processor customization, shop document preparation, and simulation. Milling includes 2.5-axis geometry typical of machinery and electronics components, and full multi-axis contour machining for applications such as tool and die, aerospace, and medical components. Turning support includes typical 2-axis applications, and also synchronized mill-turn machines and B-axis turning where

the tool pivots around a designated point. Turning operations can be created and customized from a collection of parameterized operations. General motion control provides customization of tool paths, especially probing sub-operations that can be highly customized using a collection of motion and probing elements.

NX/Open allows external software access to technology data at the operation level. This allows the reading and setting of operation parameters, and simplifies the writing of post-processors. Feature recognition is enabled based on colors and attributes, where the user defines feature types with corresponding colors and attribute criteria through a machine knowledge editor. Users can add face attributes and assembly information such as tolerances to features. The target application is complex feature geometry.

NX-CAM automates the generation of shop documentation to provide graphical and tabular descriptions of machining operations. The entire setup or selected operations within a setup can be documented. Documentation templates can be customized using Microsoft Excel, making them easy for non-experts to modify. Documentation includes descriptions of each operation and associated tooling. Tooling libraries are integrated with Siemens' Teamcenter product, providing a link to databases of tools and material properties. A comprehensive set of post-processors is available for download from Siemens' post-processor library.

Graphical tool path simulation and full machine tool motion simulation are supported, so that manufacturing operations can be visualized before running on the actual equipment. Dynamic machine tool positioning lets users add machine tools to the simulation display, showing the machine tool motion as the tool is tilted, and detecting axis limits and collisions.

A software application programming interface allows third-party developers to write supplemental applications. Geometry standard output is provided in STEP, JT, and numerous other formats. Direct interfaces exist for several third-party CAD applications.

4.2.11.2 Computer Aided Manufacturing with Dassault Systèmes

Israel Flores, Dassault Systèmes

Dassault Systèmes wants to extend the 3D master model to include manufacturing information and procedures. The company's main design product, CATIA, has evolved from 3D design in Version 3, through 3D digital mock-up in Version 4, 3D product lifecycle management in Version 5, to a full 3D experience in Version 6. Even in the presence of full 3D model data, some master data can only be accessed through 2D drawings. Therefore, Dassault is moving toward 100% 3D definition as the single master reference, with 2D representations used only for presentation. This 3D master model covers engineering (requirements and design), manufacturing process planning (work instructions, equipment programs, and technical publications), and production (shop floor review and quality inspection). Suppliers, customers, partners, and authorities all interface to this 3D model.

The shop floor and part ordering systems need executable, clear, and precise work instructions with associated configuration-managed 3D master information that includes all engineering changes. This information communicates model-based engineering requirements (tolerances, standard parts, specifications, etc.) based entirely on a parameterized 3D dataset, moving design, engineering, and simulation analysis data downstream through work instructions, supplier condition, and technical documentation. Manufacturing information includes manufacturing and routing sequences, assembly validation, work instructions, manufacturing views, buy-off and sign-off certificates, data collection, and quality check results. Design intent is conveyed to up-front activities such as planning, off-line programming, simulation, and validation.

STEP is the Dassault strategic format for long-term archiving and interoperability. STEP evolution has been driven by customer consortia: ProSTEP, PDES Inc., and LOTAR. Dassault's involvement in STEP has taken place over a long period, with support for AP203 [14] and AP214 [15] available since CATIA Version 4, circa 1994. Dassault has extended STEP support to a wide variety of applications: geometry, assembly, 3D dimensions and tolerances, composites, and electrical systems.

Dassault has advocated for representation of manufacturing information such as GD&T using polylines as the simplest and most reliable way to achieve PMI exchange for human interpretation. The representation of validation properties improves the quality of data transfer and archiving for LOTAR; these properties include the distances between control points on surfaces, and the length, center of gravity, and validation strings for PMI.

For long-term archiving of manufacturing information, low-level process information such as Automatically Programmed Tool language [16] or direct tool path data are not useful. When exchanging process information between CAM systems, higher-level information is the record of authority. Specific numerical control code programs can be recreated from this high-level exchange information. A neutral format for the exchange of high-level CAM data would be a welcome advancement, but the complexity and wide range of this information makes it difficult to standardize. Intellectual property protection is an important consideration for long-term archiving of CAM data. An industry effort should take place to develop a standard CAM data format meeting the above requirements.

4.2.11.3 Engineering Data Exchange and the Manufacturing Supply Chain

Hanan Fishman, Delcam

Delcam uses a "direct modeling" approach that reduces some problems with geometry data exchange: part complexity, productivity, data reuse, litigation, longevity, and traceability. The cost of data translation was highlighted in a 1999 NIST report [17] that calculated a $1B cost to the automotive industry, and in a 2008 report in *MoldMaking Technology* [18] that claimed 90% of toolmakers receive less than half their customers' models in the toolmaker's preferred format, with 42% of toolmakers using four or more CAD systems in a given month.

Costs arise from several activities:

- Data translation
- Model repair
- Confirming that repairs are correct
- Maintaining multiple CAD systems
- Hiring or training staff to operate multiple systems
- Translating files to return to the customer

Attempting to solve these problems by relying on a single vendor's application suite won't work because OEMs and contract manufacturers use different systems, OEMs change the systems they use, new versions of the same system often aren't compatible, and systems disappear from the market. Reliance on a single application suite also reduces effectiveness. No single software suite is the best for everything. The needs of the OEM manufacturer are not the same as those of the contract manufacturer. Being the best at data management and design does not make one the best at NC programming. And OEMs can afford to pay more for software than smaller contract manufacturers.

Sophistication of geometric modeling, from wireframes to surfaces to solids, is increasing. However, solid models still suffer from problems that can be characterized as "dumb" versus "smart". A dumb model is one without any history of modeling operations, perhaps arising from a conversion of a surface model. A dumb model may have intentional benefits, though: designers may not want to send outside manufacturers the actual modeling details for concern of divulging intellectual property, and designers don't want to send out more information than they need to get the part made.

A direct modeling approach is useful for data repair. Automated or semi-guided tools can fix problems such as gaps or overlaps in surfaces, duplicated or missing surfaces, or poor quality of trimmed edges. Direct modeling allows for making rapid, history-free edits to solids where surrounding faces automatically extend and re-intersect, maintaining a fully closed solid at all times.

4.2.11.4 CAM to CAM Data Exchange

Martin Hardwick, STEP Tools, Inc.

The ISO 10303-238 STEP-NC standard is the manufacturing process component of a TDP that serves to exchange information across a variety of activities: design, tooling and fixture design and configuration, machining resource descriptions, the manufacturing processes themselves, and overall factory control.

Time and monetary costs differ in three alternative scenarios in which an OEM contracts with a supplier for manufacturing assemblies. In the traditional scenario where the OEM owns the process and the related resources (machines, tools, and fixtures), direct monetary costs to the

OEM are highest. If the supplier owns the process and resources – a recent trend in the aerospace industry, the OEM incurs more time costs. However, in a standards-based scenario, where the OEM and supplier share the process, both monetary and time savings result.

If process information cannot be shared between customers and suppliers, unnecessary costs arise: visits to suppliers to explain models, maintenance of additional machines, repetitive error-prone data entry, misunderstandings over drawing symbols, and incomplete simulations. The desired solution is based on science, not art. Recent editions of information exchange standards include true manufacturing information (such as tolerances) in a meaningful form, and are a big step toward realizing the science-based approach. Having manufacturing information semantics enables accurate simulations of machining processes and the ability to determine whether a combination of machine and tools will fulfill tolerance requirements.

The STEP-NC standard models information to make machining faster and more accurate. STEP-NC information supports activities such as supply chain interoperability, on-machine feed-speed and tool-wear optimization, on-machine simulation and collision detection, and closed-loop machining and measurement. STEP-NC is based on machining features rather than point-to-point tool motion, is platform independent, and is intended to support “plug and play” between CAD and CAM systems. STEP-NC describes “what” rather than “how,” that is, “Make this geometry from this stock, by removing these features, in this order, with these tolerances, using tools that meets these requirements.”

Ten years of testing have gone into validating STEP-NC in production applications, in five phases: tool path generation from manufacturing features; CAM-to-CNC (Computer Numerical Control) data exchange without post processors; integration of machining and measurement; cutting tool and cutting process modeling; and modeling of tool wear, machine tool properties, closed-loop compensation, and accuracy prediction. Use of STEP-NC reduces process planning time for routine machining by an estimated 35% and machining time by an estimated 50% [19]. CAM vendors stand to gain an increase in the value of their software products by supporting STEP-NC for such capabilities as new applications (e.g., adaptive fixturing), advanced functions (e.g., automated feed/speed optimization), access to a much larger database of machine types, and support for long-term archiving.

In the coming months, the STEP Manufacturing Team responsible for AP 238 plans a deployment path using the so-called “boxy” test part developed by the Royal Technological University in Sweden. The deployment is split into two six-month phases, the first focusing on CAM systems writing STEP-NC output files, and the second focusing on reading these files as input. A software tool provided by STEP Tools Inc. will be used to view and verify STEP-NC files during the project.

4.2.11.5 Panel Session

Fred Proctor, Israel Flores, Hanan Fishman, and Martin Hardwick finished the session with a panel discussion during which they fielded questions from the audience, paraphrased as follows.

Q: Does STEP-NC cover additive manufacturing?

Hardwick: Yes, some models have been developed.

Proctor: An advantage to additive manufacturing is that it's largely process-free, so there is no need for tool paths. This may change as the technology becomes more widespread.

Q: What is happening in standards for additive manufacturing?

Hardwick: Draft standards need to undergo validation testing.

Proctor: An issue is that other standards committees, such as ASTM Technical Committee F42, are also working on additive manufacturing formats. It remains to be seen how this will shape up, and what harmonization is needed.

Fishman: Additive manufacturing is much more of a hardware challenge than a software challenge at this point.

Q: Has anyone attempted to share process data (as opposed to product data) for machining?

Fishman: Yes, it's difficult. A general consensus among the attendees is that there's always going to be a reluctance to share process information, for many reasons: intellectual property disclosure, possible embarrassment, and possible liability.

Proctor: The issues are largely the same as for computer software source code.

Audience Participant: There is an example from the Colt/Remington firearms manufacturer, where the government owns the technical data including some process information.

Q: Can we get the new PMI models from AP242 into AP238?

Hardwick: It could be incorporated into the next edition.

Proctor: Using STEP-NC for direct CNC programming could lead to a big productivity increase. NIST researcher Tom Kramer showed how this could be done.

4.3 Model-Based Inspection

Speakers in the Model-Based Inspection technical thrust represented a wide range of companies and expertise, with one end user and four vendors. All speakers had decades of experience of relevance to model-based manufacturing, including model-based metrology, standard metrology information modeling, and GD&T. This subsection summarizes the Model-Based Inspection presentations, two of which (4.3.2 and 4.3.4) describe efforts to address the information requirements of metrology systems for upstream activities [20].

4.3.1 3D Model-Based Scanning and Inspection

Jim Osterloh, M-7 Technologies

3D imaging and advanced prototyping techniques are the fastest way to provide the most detailed and complete information on the size, shape, and surface variation of complex objects. These objects can be as common as an industrial manufacturing facility or as unique as the wing spar of a recently developed unmanned high altitude surveillance aircraft. An accurate “as-built” visualized representation of an object can be fully integrated into the digital manufacturing process, whether it is the part itself or the plant that manufactures that part. 3D imaging results in increased reliability, more accurate documentation, decreased manufacturing cost, and improved quality and extended service lifetimes. M-7’s primary motivation for optical metrology research is speed – touch probing is slow. One of M-7’s goals is to increase machining center effectiveness via in-situ measurement and closed loop control.

M-7 is currently working in collaboration with Milltronics Manufacturing to develop on-machine laser probing. A video demonstration of this work illustrates the performance differences between a touch probe and a laser probe. The demonstration currently requires manual feedback, although automating the feedback loop would be more desirable. Surface reflectivity is a challenge when using a non-contact laser to measure locations and compare them with tolerances. A touch probe might be more suitable for measuring transparent or translucent components.

4.3.2 Model-Based Quality Metrology Enabled by Quality Information Framework Interoperability

Curtis Brown, Department of Energy/National Nuclear Security Administration Kansas City Plant

Quality is a customer requirement and is not optional. The critical requirements for successful implementation of model-based quality metrology are a fully semantic assembly tolerance representation, domain-specific shape features (i.e., measure features) and digital interoperability standards for manufacturing, assembly, and quality information. The Dimensional Metrology Standard Consortium’s (DMSC) Quality Information Framework (QIF – http://www.qifstandards.org) is a digital interoperability standard for quality information.

QIF includes an integrated information model for the real-time exchange of data between software and equipment modules in quality measurement. QIF is a suite of XML Schemas consisting of a library of reusable components and various application schemas such as Quality Measurement Plans (QMPlans) and Quality Measurement Results (QMResults). QIF was successfully piloted at the 2012 International Manufacturing Technology Show by a team of seven metrology software and equipment vendors. The team performed a live demonstration of a First Article Inspection (FAI) report compliant to the AS9102 FAI documentary standard [21]. Components of the QIF will soon emerge as an American National Standard. The DMSC is

preparing a "Product Data with PMI" (PDPMI) XML schema, a new QIF data exchange specification for CAD with PMI.

4.3.3 Model-based Inspection: Leveraging MBD for Quality Assurance

Ron Branch, Verisurf

A model-based quality measurement process offers the following advantages over a process involving 2D drawings:

- A single-source definition of all information needed to produce a quality product
- Integrated inspection processes, including the supply chain
- Elimination of errors of incorrect source referencing
- Elimination of discrepancy errors between the CAD model and separate 2D documentation

At the large scale, the goals of MBD are to accelerate time-to-market, decrease time and expense, and improve quality. MBD can be considered an integral part of achieving lean operations through the elimination of waste, particularly the time it takes to create and maintain paper-based model drawings, by allowing in-process inspection to catch possible production problems before they occur.

As more manufacturers adopt the MBD approach:

- MBD will enable digital global supply chains.
- MBD will eliminate most 2D drawings.
- The new STEP standard (AP242) will significantly enhance interoperability.
- The use of non-contact inspection and 3D scanning will increase significantly.
- Model-based inspection will lead to the emergence of cloud-based inspection databases.
- Faster closed-loop manufacturing and inspection cycles will lead to a resurgence of statistical process control.

4.3.4 Using Open CAD Formats to Bridge the Gap between Today's and Tomorrow's Standards

Tomasz Luniewski, Capvidia

In a Model-Based Enterprise, it is challenging to exchange 3D geometry using open standards that include metadata and semantic relations as defined in native CAD systems. Although information can be exchanged via native CAD formats and STEP files, there are gaps. Capvidia has developed CAP XML, a data format that captures topology, geometry, auxiliary objects, relations, features, and metadata. Metadata includes GD&T information. CAP XML arose from an internal proprietary data structure used to handle data from various CAD systems. The benefits of CAP XML are that it is open, human- and machine-readable, flexible and easy to extend, compact, has bi-directional compatibility with AP242, and covers all CAD system

structures. Capvidia is negotiating with the DMSC to donate the CAP XML schema. DMSC will harmonize it with QIF.

4.3.5 Model-Based Predictive Technologies for Dimensional Measurement

Jon Baldwin, MetroSage

Model-based measurement planning does a number of things well, such as generating collision-free probe paths and facilitating sensor orientation selection. However, model-based measurement planning does not validate GD&T, nor can it guarantee traceability or optimality. Tools such as FBTol [22] for GD&T validation can alleviate these issues.

Measurement uncertainly evaluation is important to understand many issues related to Coordinate Measurement Machines (CMMs). Model-based simulation methods can evaluate many GD&T parameters in one "experiment." There are measurement risks and costs such as false positives (classifying a good part as bad) and false negatives that usually have worse consequences than false positives.

4.3.6 Model-based Definition Enables Inspection Lifecycle Management

Sam Golan, PAS Technology

PLM is the process of managing the entire lifecycle from its conception, through design and manufacture, to service and disposal. A key to PLM success is integration, where integration provides a manufacturing information backbone. Integration involves people, data, processes and business systems.

Quality assurance is an integral part of PLM. The outsourcing of Boeing 787 systems led to quality assurance challenges that resulted in delays and increased costs. To make quality assurance a real integral part of PLM, there needs to be inspection lifecycle management. One of many inspection challenges is that it takes longer to develop a CMM program than a CNC program from the same CAD model. Inspection lifecycle management automates and manages the entire integrated quality assurance process from design to manufacturing to inspection to trusted inspection results.

4.4 Systems Engineering

The *Handbook of Systems Engineering and Management* defines SE as "the management technology that controls a total system lifecycle process, which involves and which results in the definition, development, and deployment of a system that is of high quality, trustworthy, and cost effective in meeting user needs" [23]. In the context of MBE, SE involves ensuring that a model captures functional and behavioral requirements, and that design information is traceable to these requirements. This subsection summarizes presentations focusing on the capture, tracking, and maintenance of requirements information.

4.4.1 Update on Key Model-based Engineering (MBE)-related Pursuits at NASA

Paul Gill, National Aeronautics and Space Administration (NASA)

The NASA manufacturing environment is unique. NASA is composed of independent centers. Centers have different missions, but all include engineering of some kind. Interactions between centers tend to be project-specific. NASA projects are dependent on prime contractors. Projects usually have long development and operational life cycles. Long life cycles complicate change management because they make it difficult to converge on any common approach (e.g., 3D CAD did not exist for Voyager 37 years ago). Unlike many other manufacturing enterprises, NASA builds very low volumes of complex products.

NASA's MBE development must meet the following requirements:

- Improved systems integration
- Long-term access to design data
- Integrated SE
- Conceptual engineering integration with modeling and simulation

The following are non-requirements for NASA:

- Manufacturing or supply chain coordination (due to low rates)
- Unit cost reduction (typically no more than three units of any design are built)
- Reuse of design data for new products (because missions are unique)

NASA has a long tradition of pioneering new engineering technologies to meet big challenges. The NASA Langley Research Center developed custom hardware for Finite Element Analysis in the late 1970s [24]. More recently, findings from the Columbia Accident Investigation Board [25] resulted in NASA developing new insights into the flow of data between NASA Engineering and downstream activities. Today, discipline-focused NASA Working Groups are converging on solutions addressing challenges in model-based SE, modeling and simulation, CAD interoperability, and PLM.

NASA views MBE as a way to increase efficiency and quality of critical activities such as:

- Systems modeling and simulation
- Verification and validation
- Vehicle systems integration
- Flight operations
- Prototyping and test article production
- Post-event analysis and review (e.g., in-flight anomalies)
- Concept development and proposal reviews
- Prime contractor interfaces

- Systems integration (e.g., science payloads)
- Vehicle acceptance

NASA currently has two initiatives related to MBE. The NASA Integrated Model-centric Architecture program seeks to increase affordability and interoperability within and among programs/projects, centers, and external partners through the use of a common model-centric architecture. NASA benchmarked companies using a model-centric architecture for engineering and manufacturing. Companies benchmarked included Whirlpool Corporation, Ford Motor Company, Lockheed Martin, and Pratt &Whitney Rocketdyne.

The second initiative is the Product Data Management & Interchange program. The goal of this project is to provide some data commonality among NASA projects. NASA has over ten PLM systems and numerous CAD, simulation, and analysis systems. Many current tools and architectures were selected before 3D CAD and prior to large programs like Constellation. NASA cannot dictate what systems its primes use. Detailed design work is often outsourced or handled by the primes. Individual NASA projects have a lot of authority to choose their own engineering tools, mostly because of the long duration of the projects. Many new tools are available for new projects. Project and SE policies are very inconsistent on the topic of "models." For example, one project substituted "model" wherever they had the term "drawing." Modeling practice is driven by NASA center-level policies, procedures, and handbooks.

Future goals at NASA related to MBE are:

- Cross-mapping of model maturity states to support pre-release exchange
- Improving modeling and simulation
- Moving away from document-centric engineering practice
- Digital records retention and archiving
- Configuration management for complex hybrid systems

4.4.2 Some Imperatives for Realizing Model-Based Products

Richard Neal, Integrated Manufacturing Technology Initiative

It is both possible and reasonable for the U.S. to gain and maintain a position of leadership in design and manufacturing in the global economy. However, realizing this achievement requires that we embrace new technologies, emerging processes, and cultural norms. One of the greatest enablers for success is the deployment of model-based design and manufacturing systems.

The move to a model-based manufacturing environment is not new. It has been in process for more than two decades, and dramatic and impressive successes have been realized. However, these successes are mainly isolated examples that come from implementation of parts and pieces of the total solution package. The methods and tools are now mature enough to embrace a holistic view that changes the process by which products are developed. This new environment will enable the unbounded evaluation of ideas, the extraction of requirements, the definition and

evaluation of concepts (including quantification of cost, schedule, and risk), the creation of detailed designs, and the production and sustainment of products.

SE is becoming increasingly emphasized. In today's most advanced manufacturing companies, every design or manufacturing engineer must also become a systems engineer. MBE must be integrated across the lifecycle, and should be optimized early with a clear definition of costs and risks.

4.4.3 Model Standards Interoperability across Domains, the Life Cycle, and the Supply Chain

Charlie Stirk, Cost Vision

There are many complementary interoperability standards for models across functional domains such as program and project management, SE, mechanical design, visualization, simulation, logistics, and data management and lifecycle stages. The interfaces between these data model standards need to be defined to enable interoperability across the functional domains. These interfaces must specify where standards overlap as well as fill gaps. Managing all of these standards and the interfaces between them, while at the same time promoting deployment, is a challenge.

Several ongoing efforts and developments are helping to manage standards complexity and facilitate implementation and adoption. The LOTAR International consortium is developing and portfolio-managing a standards technology roadmap for ISO 10303 (STEP) and related standards to ensure that changes improve interoperability. Technologies for model transformation, web service interfaces, web browser interfaces, and secure collaboration are maturing and enabling applications such as supply chain collaboration and integrated data environments. Standards development frameworks such as the STEP modular architecture for ISO 10303 standards and the Product Life Cycle Support framework (http://www.plcs.org) for data exchange specifications lower standards development costs by providing repositories of reusable building blocks and automating quality assurance. Implementer forums are conducting interoperability testing, providing feedback to standards bodies, and documenting best practices for implementing standards. Finally, open source reference implementations such as STEPcode (http://stepcode.org) can increase standard quality and adoption in software.

Additional investment is needed in these efforts. In particular, road mapping efforts should be expanded to standards other than those in the ISO 10303 family. Also, more resources are needed to improve existing standards development frameworks, expand the number of implementer forums, and encourage the development of additional open source implementations.

4.4.4 Evolving Lockheed Martin's Engineering Practices through the Creation of a Model-centric Digital Tapestry

Tom Hannon, Lockheed Martin Corporation

There is a lack of effective integration across different engineering disciplines. Most existing integrations are point-to-point. The Model-centric Digital Tapestry is a framework and strategy for achieving a more holistic and cross-cutting integration that meets the challenge of DoD's Systems 2020 vision. The digital tapestry is a single source of truth. Systems Modeling Language (SysML) [26] enables the digital tapestry by allowing us to tie together all the different, cross-disciplinary pieces of information.

SysML is the hub of the digital tapestry. It allows us to connect threads of information together and link requirements across domains. System-level analysis drives the CAD reference architecture. An integrated propulsor analysis pilot successfully used this SysML-enabled digital tapestry approach to increase the accuracy of vehicle assessments.

Our business case analysis for using SysML determined that the benefits exceed the upfront costs of doing the modeling, assuming that the necessary information technology infrastructure already exists.

4.4.5 IBIF Projects and Business Case Analyses

Denise Duncan and Cindy Flint, LMI Government Consulting

The Industrial Base Innovation Fund (IBIF) is part of OSD's Defense-Wide Manufacturing Science and Technology program. IBIF's two technical areas are (1) Comprehensive TDPs for next generation business exchanges, and (2) TDP integration and validation for government delivery. LMI is helping IBIF TDP project teams develop high-level business case analyses and is completing a white paper making the case for MBE. MBE practitioners (including those participating in this Summit) are increasingly making use of business case analyses. The community can benefit if we consolidate our respective business cases and make them available as a common resource.

Although the template for a business case varies depending on agency or Service, size of dollar investment, and type of investment (e.g., research, information technology, major system), the following are standard steps in developing any business case:

- Define the "as is" case, i.e., the status quo.
- Define alternatives for addressing problems with the status quo.
- State assumptions made in the business case analysis, document pertinent policies, name stakeholders, and describe potential benefits.
- Conduct an economic analysis using methods such as Net Present Value, statistical modeling, and cost/benefit ratio.

5 Conclusions

The 2012 MBE Summit brought together a wide variety of organizations spanning both public and private industry sectors. Speakers included manufacturers, quality experts, researchers, and software solution providers. Industry attendees were from both large and small companies. The following are among the conclusions that emerged from the Summit.

Model-based methods and tools are increasing manufacturing productivity, but challenges remain.

Dean Robinson (4.2.1) reported that his employer was able to reduce tooling design time 75% by using model-based methods, yet he also acknowledged the key challenges of introducing advanced materials such as composite structures, and advanced processes such as additive manufacturing. Lack of a full 3D representation and good visualization methods limit the application of MBE to manufacturing involving composite materials [27]. Because additive manufacturing information requirements are complex and additive processes are fault-sensitive, even the smallest data error in a model can lead to part defects that are not detectable by visual examination [28].

Martin Hardwick (4.2.11.4) asserted that removing barriers to sharing process data has the potential to greatly lower manufacturing costs, reduce data entry errors and misunderstandings over drawing symbols, and reduce the need for suppliers to explain models. However, new research and development are needed to address challenges such as intellectual property protection and adapting to changes in tooling, setup, or machine tool performance.

Model-based inspection combined with optical measurement techniques is a potential game changer.

As Jim Osterloh (4.3.1) pointed out, optical scanning is faster and more accurate than touch probing, and enables "as-built" visualized representations of objects to be generated prior to manufacturing. The 2012 Summit presentations and subsequent panel discussions on model-based inspection indicate a groundswell of interest in the integration of the inspection, design, and production activities in manufacturing via a standards-based digital model-based approach. Jim Osterloh (4.3.1) demonstrated and Ron Branch (4.3.3) discussed the dramatic potential for optical scanning combined with MBE. Curtis Brown (4.3.2) described a successful pilot implementation of the QIF standards for model-based inspection.

Lightweight visualization formats are making MBE feasible for SMEs.

Lightweight formats such as 3D PDF are gaining traction in TDP implementations, and companies accustomed to 2D engineering drawings are now experiencing the benefits of MBE. Ric Norton (4.1.2) reported on U.S. Air Force deployment of a 3D PDF TDP for A-10 wing

replacement. David Stieren (4.2.2) and Sanjay Parimi (3.2.8) both reported a strong and growing preference among manufacturers in the Army supply chain for 3D TDPs over 2D drawings.

Systems Engineering is an increasingly important component of MBE.

Manufacturing is becoming more assembly-centric, and products are becoming increasingly complex and multi-functional. The consequence, as Richard Neal (4.4.2) pointed out, is that "every design or manufacturing engineer must also become a systems engineer." Tom Hannon (4.4.4) reported success using SysML to improve integration across multiple engineering disciplines throughout his company. Charlie Stirk (4.4.3) recommended that industry standardize more interfaces across functional domains, and that those creating the standards should use roadmaps to better coordinate and manage standards development and deployment.

Open standards and reference implementations are critical.

The continued success of MBE requires deployment of open standards for representing and exchanging product and process data. As we stated in Section 3, product data standards are widely implemented today, but manufacturing process data standards have only had limited industry success. Harold Owens and Brent Gordon (4.1.4) highlighted the need for standardized 3D model acceptance criteria to ensure product quality. Charlie Stirk (4.4.3) made a case for open source reference implementations as a catalyst for standards deployment. Martin Hardwick (4.2.11.4) pointed out that when manufacturing processes are non-proprietary and standards-based, OEMs can save both time and money.

6 References

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Appendix: Final Agenda and Presentation Materials

The following pages contain:

1. The final MBE/TDP Summit agenda
2. Presentation materials from all Summit speakers who gave NIST permission to distribute their slides.

To minimize page count, each page of presentation materials contains six slides. In some cases, we deleted slides determined to be content-free (e.g., "Thank you" and "Any questions?" slides) and slides that were partial builds of other slides (useful for "animating" presentations but not of much value in a printed hard copy).

With the exception of the two presentations given by NIST staff (4.2.2 and 4.2.7), inclusion in this Appendix implies neither endorsement nor approval by the National Institute of Standards and Technology.

MBE Summit

NIST, Gaithersburg, MD
Green Auditorium, Bldg101

Tuesday, 11 December, 2012

Time	Topic	Speaker(s)
0830-0840	Introductions and Admin	Simon Frechette, NIST Paul Huang, ARL
0840-0940	Welcome and Opening Remarks	Shyam Sunder, Director, NIST Engineering Laboratory Adele Radcliff - OSD ManTech Phil Zimmerman - OSD AMSWG
0940-1010	Model-Based Manufacturing	Dean Robinson, GE Global Research
1010-1040	DLA Overview	Richard Norton, DLA-LIS
1040-1100	**Break**	
1100-1130	NAVAIR EIPT	Howard Owens, NAVAIR
1130-1200	3D Model Based Scanning & Inspection	Fred Persi, M7 Technologies
1200-1240	Vendor Updates	
1240-1330	**Lunch Break & Vendor Demos**	
1330-1400	The Quality Information Framework: MBE and XML Schema Models	Curtis Brown, Honeywell FM&T
1400-1430	Model Based Inspection: Leveraging Model Based Definition for QA	Ron Branch, Verisurf
1430-1500	Using Open CAD Formats to Bridge the Gap Between Today's and Tomorrow's Standards	Tomasz Luniewski, Capvidia
1500-1530	**Break & Vendor Demos**	
1530-1600	Model-Based Predictive Technologies for Dimensional Measurement	Jon Baldwin, Metrosage
1600-1630	Inspection Lifecycle Management	Sam Golan, PAS Technology
1630-1700	Model Based Inspection Panel: Q&A	Moderator: John Horst
1700-1830	Wrap-Up and Vendor Demos	

Website: http://www.nist.gov/el/msid/mbesummit_2012.cfm

MBE Summit

NIST, Gaithersburg, MD
Green Auditorium, Bldg 101

Wednesday, 12 December, 2012

Time	Topic	Speaker(s)
0800-0810	Announcements & Admin	Simon Frechette, NIST Paul Huang, ARL
0810-0840	NIST EL Manufacturing Program Overview	Simon Frechette, NIST
0840-0910	Air Force Advanced Manufacturing Overview	Brench Boden, AFRL
0910-0940	NASA MBE Effort	Paul Gill, NASA
0940-1010	**Break**	
1010-1040	Open Manufacturing	Mick Maher, DARPA-DSO
1040-1110	Implementing Model Only at Cubic Defense Applications	Peter Buzyna, Cubic Defense
1110-1140	The Sustaniable Enterprise: Enabling the Digital Thread	Karen Kontos, Honeywell
1140-1210	NDEMC, Affordable Access to Modeling & Simulation and High Performance Computing for SMEs	Dennis Thompson, SCRA
1210-1230	NAMII Overview	Ed Morris, Director NAMII
1230-1330	**Lunch Break & Vendor Demos**	
1330-1345	Lightweight Formats/Visualization Overview	Rich Eckenrode, Recon-Services
1345-1410	3D PDF Format	David Opsahl, 3D PDF Consortium
1410-1435	Repurposing of Engineering Data	Chris Garica, Anark
1435-1500	A New Dimension in Data Sharing	Tom Barth, EOS
1500-1530	**Break & Vendor Demos**	
1530-1555	JT Overview	Dennis Keating, Siemens
1555-1620	Creo View	Mark Nielsen, PTC
1620-1645	3D Via	Dassault Systems
1645-1700	Vendor Panel Discussion	Moderator: Rich Eckenrode
1700-1830	Vendor Demos in Hall of Flags	

Website: http://www.nist.gov/el/msid/mbesummit_2012.cfm

MBE Summit

NIST, Gaithersburg, MD
Green Auditorium, Bldg101

Thursday, 13 December, 2012

Time	Topic	Speaker(s)
0800-0810	Announcements & Admin	Simon Frechette, NIST Paul Huang, ARL
0810-0830	NIST MEP Update	David Stieren, NIST MEP
0830-0900	TDP for the Digital Enterprise	Denise Duncan, LMI
0900-0930	Army Advanced Manufacturing Overview	Sanjay Parimi, ARDEC
0930-1000	**Break**	
1000-1050	Imperatives for Achieving Model-Based Product Realization	Richard Neal, IMTI
1050-1140	Model Standards Interoperability Across Domains, the Life Cycle, and the Supply Chain	Charlie Stirk, CostVision
1140-1230	The Lockheed Martin Model-Centric Digital Tapestry	Tom Hannon, Lockheed Martin
1230-1330	**Lunch Break**	
1330-1345	Manufacturing Processes Overview	Fred Proctor, NIST
1345-1410	Siemens Overview	Dennis Keating, Siemens
1410-1435	Dassault Overview	Israel Flores, Dassault Systems
1435-1500	Delcam Overview	Hanan Fis, Delcam
1500-1515	**Break**	
1515-1540	CAM Standards	Martin Hardwick, STEPTools
1540-1645	End-User Panel Discussion	Moderator: Fred Proctor
1645-1715	Wrap-up and Path Forward	Paul Huang

Website: http://www.nist.gov/el/msid/mbesummit_2012.cfm

DoD Modeling and Simulation Support to Acquisition

Ms. Philomena "Phil" Zimmerman
ODASD(SE)/System Analysis

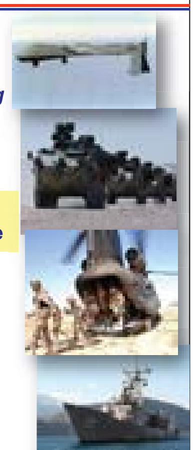
National Institute of Standards and Technology (NIST)
Model-Based Enterprise Summit
December 13, 2012

Agenda

- Modeling and Simulation within ODASD(SE)
- Modeling and Simulation Observations
- Modeling and Simulation Fundamentals
- System Modeling and DoD Acquisition
- Engineered Resilient Systems

DASD, Systems Engineering Mission

Develop and grow the Systems Engineering capability of the Department of Defense – through engineering policy, continuous engagement with component Systems Engineering organizations and through substantive technical engagement throughout the acquisition life cycle with major and selected acquisition programs.



A Robust Systems Engineering Capability Across the Department Requires Attention to Policy, People and Practice

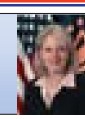
We apply best engineering practices to:

- Support and advocate for DoD Component initiatives
- Help program managers identify and mitigate risks
- Shape technical planning and management
- Provide technical insight to OSD stakeholders
- Identify systemic issues for resolution above the program level

DASD, Systems Engineering

DASD, Systems Engineering
Stephen Welby

Principal Deputy
Kristen Baldwin



Systems Analysis Kristen Baldwin (Acting)	Major Program Support James Thompson	Mission Assurance Nicholas Torelli
Addressing Emerging Challenges on the Frontiers of Systems Engineering	*Supporting USD(AT&L) Decisions with Independent Engineering Expertise*	*Leading Systems Engineering Practice in DoD and Industry*
Analysis of Complex Systems/Systems of Systems Program Protection/Acquisition Cyber Security University and Industry Engineering Research Modeling and Simulation Systems Engineering FFRDC Oversight	Engineering Assessment / Mentoring of Major Defense Programs Program Support Reviews OIPT / DAB / ITAB Support Systems Engineering Plans Systemic Root Cause Analysis	Systems Engineering Policy & Guidance Development Planning/Early SE Specialty Engineering (System Safety, Reliability and Maintainability Engineering, Quality, Manufacturing, Producibility, Human Systems Integration (HSI)) Technical Workforce Development Standardization

Providing technical support and systems engineering leadership and oversight to USD(AT&L) in support of planned and ongoing acquisition programs

Observations: Call for Action

- **Modeling and Simulation is not consistently applied in the acquisition lifecycle**
  - It is not consistently recognized as a component or enabler of Systems Engineering
  - It is not consistently productive for the program management team
  - It is inconsistently applied in phases of the acquisition lifecycle
- **They are never used as a continuum of tools, or as a supplier of rationale and justification for analysis, evaluations, and assessments across the acquisition lifecycle**
  - It is not consistently represented in Service and component organizations
  - It is not, as a community, organized to answer questions, fill SE gaps, or share best practices
- **Modeling and simulation has a long-standing strategy, but it does not have a current roadmap for improvement in application**
  - Acquisition modeling and simulation needs, capabilities, messages from PEO, PM not reaching OSD; and vice versa
- **Contemporary challenge: Mr. Kendall's remarks at CSIS, 6 Feb 2012**

MS&A Fundamentals

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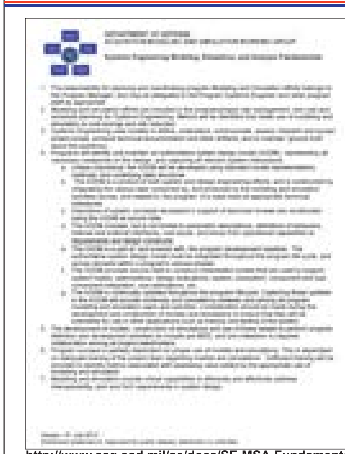
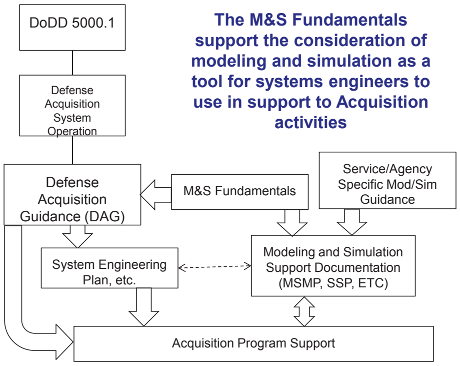


http://www.acq.osd.mil/se/docs/SE-MSA-Fundamentals.pdf

- **Purpose:** One page that conveys a high-level, concise, and comprehensive set of truths for Mod/Sim usage in Systems Engineering support to programs
- **Key Areas Emphasized:**
  - Program Systems Engineer is responsible for Mod/Sim planning and coordination
  - Mod/Sim is included in key schedule and programmatic plans
  - SE uses models to define, understand, and communicate technical artifacts
  - Models are continually updated throughout program life-cycle
  - Project success is dependent on appropriate Mod/Sim training of team

Using the Modeling and Simulation Fundamentals



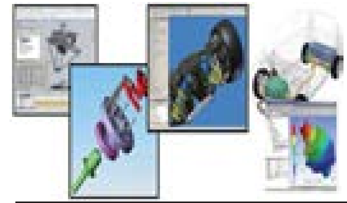
The M&S Fundamentals support the consideration of modeling and simulation as a tool for systems engineers to use in support to Acquisition activities

- **The Fundamentals connect the M&S community to the acquisition use of M&S**
- **The Fundamentals suggest how M&S should be incorporated into the SE position on the program, but do not dictate how**
- **The Fundamentals assist both OSD and the programs maintain a common understanding of M&S use for acquisition program support**

The M&S Fundamentals provide the modeling and simulation basis of support for programs, posturing modeling and simulation as a part of systems engineering, not separate from it.

Systems Modeling Use in Acquisition A 10,000 Ft View of the Practice

- **The use of models and the insights gained from their use, aid in the conceptualization, resource estimation, design, deployment and sustainment of systems**
- **It is not limited to engineering; it enables engineering rigor across all acquisition functions**
- **The tools and processes for systems modeling use enable acquisition functions to be more efficient**
- **"Modeling" refers to a wide range of artifacts, to include physical and computer based**
- **Application of models supports reduction of program uncertainties, at any point in time, in cost, schedule, and performance**



The concept is still maturing
- **In far more use that often recognized**
- **Has proven to be powerful when used**
- **Is not perfected, and *requires intelligent use***
- **Adoption has been uneven across DoD to date**

Model based acquisition does not diminish the importance of simulations; it increases the relevance of simulation output through consistent use of complete models

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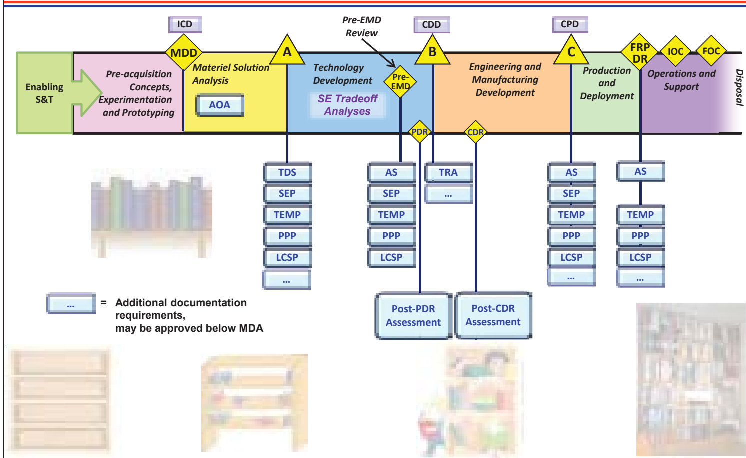
Acquisition Life Cycle Framework
"Weapon System Development"



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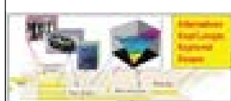
Why? Engineered Resilient Systems Key Technical Areas

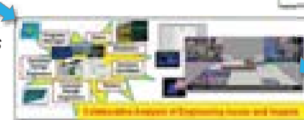
Systems Representation and Modeling
- Physical, logical structure, behavior, interactions, interoperability…



Characterizing Changing Operational Contexts
- Deep understanding of warfighter needs, impacts of alternative designs

Cross-Domain Coupling
- Model interchange & composition across scales, disciplines

Data-driven Tradespace Exploration and Analysis
- Multi-dimensional generation/evaluation of alternative designs



Collaborative Design and Decision Support
- Enabling well-informed, low-overhead discussion, analysis, and assessment among engineers and decision-makers

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Summary

- **The Modeling & Simulation Fundamentals are one of the Keystones (NOT POLICY) of Consistent Modeling and Simulation Support to Programs**
  - Established by the Acquisition Modeling and Simulation Working Group as a simple way to bridge the M&S community with the acquisition community.
- **Prove the best practices (real and expected) before applying the System Model**
  - Discover/Identify best practices based on examples from the Services/Agencies
  - Develop definition, build business case by studying elements in existence today
- **Develop the System Model from elements and artifacts of acquisition activities which already exist**
  - Do not invent anything new; instead, use 'aim points' from that which already exists
  - Population of the system model should not require separate contract clauses

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MS&A Presentations

Richard Neal - The Integrated Manufacturing Technology Initiative
"Imperatives for Achieving Model-Based Product Realization"

Charlie Stirk - CostVision Inc
"Model standards interoperability across domains, the life cycle, and the supply chain"

Tom Hannon - Lockheed Martin Corporation
"The Lockheed Martin Model-Centric Digital Tapestry"

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DEFENSE LOGISTICS AGENCY
AMERICA'S COMBAT LOGISTICS SUPPORT AGENCY


A-10 Pilot Program Overview "DLA Engages Model Based Enterprise"

Defense Manufacturing Conference

November 26, 2012

Ric Norton

Distribution Statement A: Approved for public release; distribution is unlimited

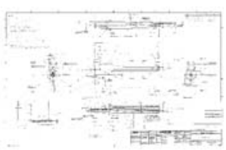
Overview

- Needs and Benefits
- Data for National Stock Numbers (NSN)
- Why Quality Data is Important
- A-10 Existing and Emerging Technologies
- Metrics, Results of using Model Data
- Progress to date with A-10
- DLA Moving Closer to use of Model Data
- Questions

Needs….

'As Is' environment
Current DLA information systems rely on flat files and face data quality problems

80-Column Coded Data



Degraded 2D drawings

U.S. AIR FORCE

Move Capability from 2D drawings to 3D digital data

Modernize Data and Data Exchange

'To Be' environment:
Comprehensive Product Life Cycle System that uses 3D models, digital data, to include logistics product data,… married in the Product Lifecycle Management (PLM) system and exported downstream

…and Benefits

- "R4" -Right Part, Right Place, Right Time, Right Money
- Fewer people will be needed to develop, use, reuse, and archive better quality data
- Digital Thread (data exchange) between PLM, AF Legacy, FLIS, DLA Supply Chain ERP
- "Light, standard, economical, highly effective" Model Data for "Supply Chain User" 3D PDF
- Model Data, early on, enhances "Rapid Fielding" without sacrificing "Sustainment"

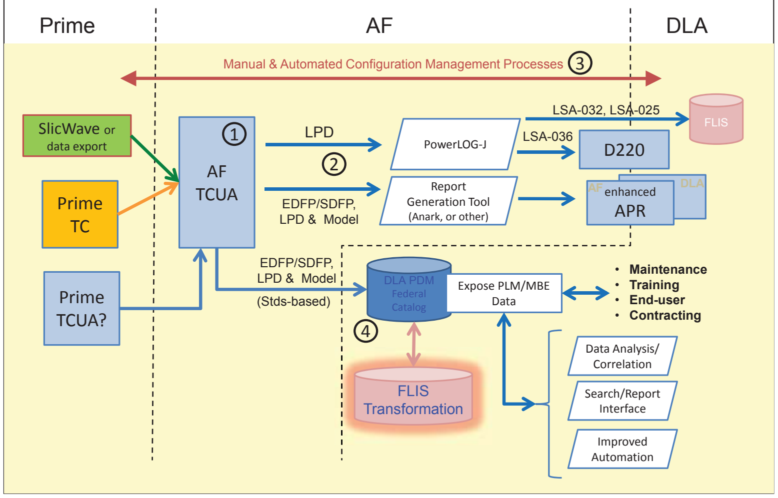
Data for National Stock Numbers (NSN)

Data to identify, classify and describe an item is extremely important.

Equally important is the management information or the Logistics Product Data (LPD) codified under each NSN used throughout a product's total lifecycle- ref the "NSN Wheel"

Why Quality Data is Important

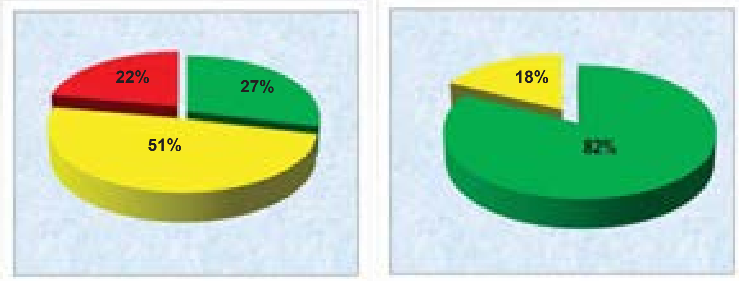
A-10 Existing/Emerging Technologies



Metrics- Results of using Model Data

Active NSNs in FLIS* Database

A-10 Wing Replacement Initial NSN Assignment



Fully Described NSNs   Partially Described NSNs   Non-described NSNs

*Federal Logistics Information System – 6.6M active NSNs as of Oct 2012

Progress to date with A-10

- A-10 Wing Replacement Program (WRP) Provisioning Parts List (PPL) (36,000+ items
- PPL is scheduled to be delivered with supporting Technical Data Package (TDP) to Air Force and DLA Provisioning Offices November 30
- Approximately 856 items have been identified as procurable (P coded) items.
- Engineering Data for Provisioning will include approximately 690 3D PDF Models and some vendor provided 2D data.

DLA Moving Closer to use of Model Data

- Model data provided to DLA Logistics Technicians will be a 3D PDF "derivative" aka "Technical Part Report" (TPR)
- TPR will be embedded in Associated Provisioning Data Report (APDR), a 2D PDF file which contains attribute fields for analytical and management associated data not in TPR
- DLA will identify, classify, and codify parts with Model Data…48 Technicians trained in October

DEFENSE LOGISTICS AGENCY

AMERICA'S COMBAT LOGISTICS SUPPORT AGENCY

Contracting for Technical Data Packages (TDP) within a Model Based Enterprise (MBE)

Defense Manufacturing Conference

November 29, 2012

Ric Norton

Overview

- Needs…. and Benefits
- Contracting for What Types of Data
- Existing and Emerging Technologies
- Intended Results of this Project
- Progress to Date
- Why DLA is a Major Stakeholder
- Questions

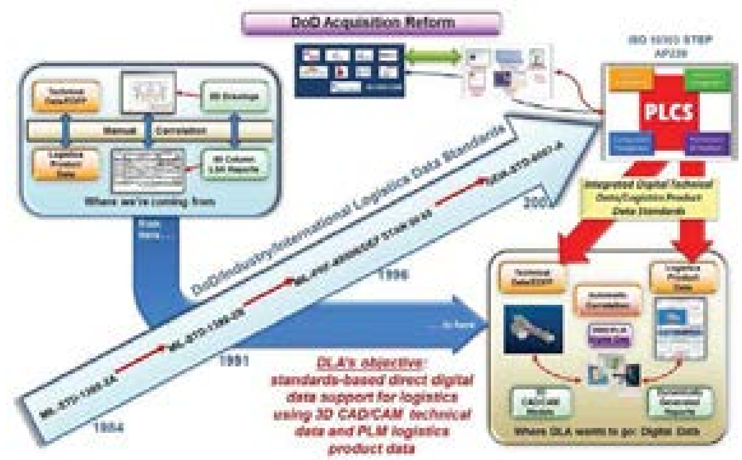
Needs….

- Ensure Standards and Specifications used as references to drive all TDP requirements are adequate
- Ensure Data Item Descriptions (DIDs) are written and tailored properly within the Contract Data Requirement Lists (CDRLs)
- Ensure those who write these requirements in contract are prepared to do so or are facilitated by Subject Matter Experts (SMEs) who are
- Ensure Program Executive Officers and Managers are prepared to implement efficient and effective Data Management Strategies

….and Benefits

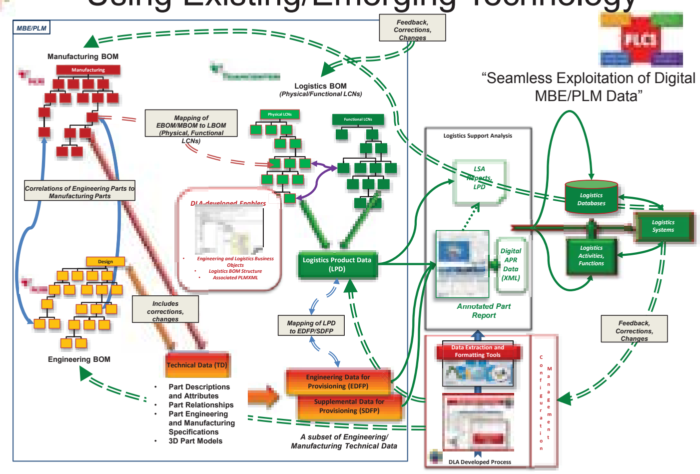
- Technical Data Requirements that allow for an efficient digital means to exchange valid quality data from authoritative sources to all downstream supply chain users.
- The contract will clearly state these requirements so there is no question on producing deliverables that meet the "how, what, when, where, why criteria…"
- Will ensure interoperability

Contracting for What Types of Data



Using Existing/Emerging Technology

"Seamless Exploitation of Digital MBE/PLM Data"



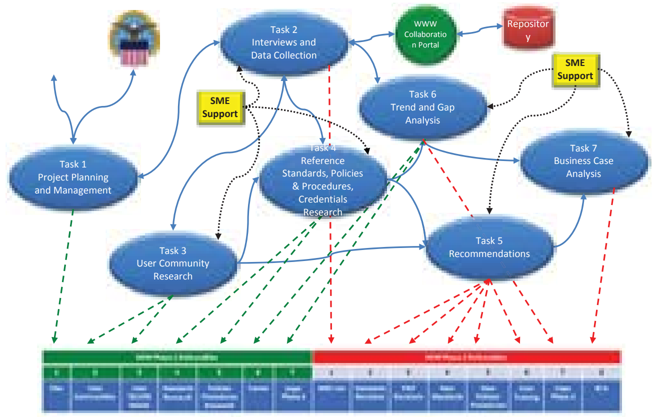
Intended Results of this Project

- Gap and Trend Analysis will identify what we have and what is needed in:
  - Policies/procedures
  - Referenced Specifications and Standards
  - Statements of Work (SOWs)
  - Data Item Descriptions (DIDs)
  - Contract Data Reference Lists (CDRLs)
  - Implementers and Systems
- BCA will identify what is effective and recommend what is needed to improve "Contracting for TDP within MBE"

Progress to Date

- Representative sample programs (RSPs) are being analyzed to determine how TDP and data exchange requirements are currently being satisfied.
- This data coupled with other research is being used to prepare a Gap and Trend Analysis as well as a Business Case Analysis (BCA)
- RSPs include programs from all Military Services USCG, NASA… different depots, primes, and category programs are being researched.

Progress to Date



Why DLA is a Major Stakeholder

- DLA is a major parts provider for most fielded weapons systems
- We do business with all the Primes, all the Services, and the Supplier Base in support of the Warfighter.
- We must proactively seek or develop an "Interoperable Digital Data Exchange Strategy" that will enable us to continue….

Key Points

Support the Warfighter with good Data

Contract Number:	SP4701-09-D-0032
Title:	Contracting for Technical Data Packages (TDPs) within Model Base Enterprise (MBE)
Performing Activity:	Defense Logistics Agency
Objectives:	Research & Develop effective means to contract for TDP Deliverables within MBE - Determine how to contract for Model Data - Determine how to contract for Logistics Product Data
Start / End Dates:	Start 12/2010 End 12/2012
DLA Investment:	$500K Budgeted
Cost Share:	$ N/A
Weapon System:	**N/A**

Performing Entities:

- DLA J334- DLIR Program management
- DLA J62 – Executive Sponsor
- DLA Logistics Information Service – Co-sponsor/Project Lead
- Decision/analysis Partners LLC

Technical Achievement:

- N/A

Implementation:

System:	N/A
Site:	DLA Logistics Information Service
Schedule:	
Status:	Analyses being compiled for Gap Trend and Business Case
Cost	Within budget
Schedule	On schedule
Technical	Drive Deliverables in contact for 3D Models, Data exchange of XML Schema and Data Exchange Sets (DEXS)
Payoff:	Source for Effective means to drive TDP contract requirements

NAVAIR

Technical Data Package Lifecycle Management

Presentation for
NIST
Howard Owens/Brent Gordon
December 11, 2012

Agenda

- Purpose
- TDP Lifecycle Management Issues/Risks
  - ➢Magnitude of the Problem
- What are we doing?
  - ➢Enterprise IPT
  - ➢PLM Projects/Pilots

Purpose

- Provide summary of Technical Data Package (TDP) Lifecycle Management issues and risks
- Advise leadership of current efforts with Technical Data Package Lifecycle management
  - o Enterprise IPT established and chartered as a result of risk associated with native 3D models
  - o Product Lifecycle Management (PLM) pilots and projects initiated

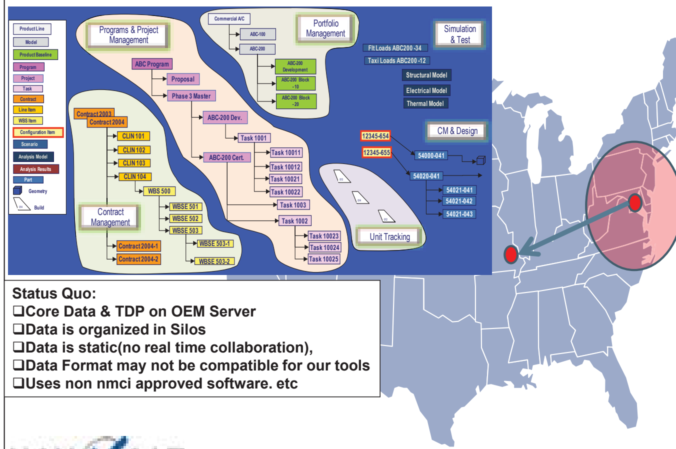
TDP Lifecycle Management Issues and Risks

Acquisition → QA → Store (DoD/N Repository or CITIS) → Translation(s)/ Healing(s)/QA → Use

- Acquisition Requirements non-standardized
  - Inadequate exit strategies from OEM PLMs
  - New acquisition programs (e.g. BAMS, UCLASS, H-53K) looking for enterprise PLM/repository solution
- QA - No standardized 3D model acceptance criteria
- Storage - No central repository /workflow tool
- Multiple online CITIS/IDE solutions
  - OEM Managed & Owned
- Static/Baseline Deliveries via Hard Drive
- Multi CAD translation - lack of software, hardware, connectivity, and training
  - No standardized 3D Model validation criteria for translated/healed models
  - Creates potential void in first article testing/air worthiness item compliance
- Digital file availability and lack of control may compromise design agency
- Model defects not recognized until used
  - Model often does not match OEM "As Built" or "As Delivered" requiring reverse engineering efforts
  - Item cannot be correctly manufactured or re-procured from the model delivered

TDP Lifecycle Management Issues and Risks

Millions Spent Annually on IDE's to Maintain Data That is Disconnected and Controlled by OEM's



Status Quo:
- **Core Data & TDP on OEM Server**
- **Data is organized in Silos**
- **Data is static(no real time collaboration),**
- **Data Format may not be compatible for our tools**
- **Uses non nmci approved software. etc**

What are we doing?

- **Enterprise Cross Competency IPT chartered:**
  - **Project Sponsor:** Dan Nega (SES) AIR 6.8
  - **Process stakeholders:** Dennis West COMFRC (SES), Stu Young AIR 4.1 (SES), Jack Summers (SES), AIR-00-CIO, Anthony Manich, AIR 1.0A Deputy Assistant Commander for Acquisition
- **Goal Statement:**
  - Standardize the acquisition and sustainment of TDPs
  - Provide our work force with the tools, training, infrastructure, and processes required to be successful.
- **Problem statements:**
  - NAVAIR Engineering remains disconnected from OEM/Vendor Engineering environment, leading to continued lengthy development cycles, late discovery of deficiencies, and misinterpretation of requirements, perpetual engineering approval loops, and overall poor communication
  - Current acquisition environment emphasizes the need for the government to act as the Lead Systems Integrator (LSI), but it does not emphasize the procurement of the TDP.
  - NAVAIR logistics, engineering, and production information systems used for sustainment are not integrated, lack standardization throughout the enterprise, and were not designed to handle CAD/CAM/CAE data used for 21st century platforms.

NAVAIR 3D Enterprise IPT

3D EIPT Leadership:
- Dan Nega AIR-6.8, Dennis West COMFRC, Stu Young AIR-4.1

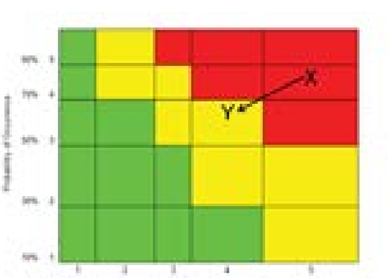
3D EIPT Membership includes:
- 1.1.3 Configuration Management
- 2.5.1.6 A/C Support Contracts, Logistics & In-Service Support Centers Contracting Br
- 4.1.9 Systems Engineering, Manufacturing & Quality Div
- 4.5.8.2 Air Traffic Control Systems, Approach Systems Br
- 5.4.3.1 Battlespace Simulation & Test, Enterprise Operations Br
- 6.0H COMFRC
- 6.6 DPMLs
- 6.8.4 Aviation Readiness & Resource Analysis, Logistics & Maintenance Information Systems & Technology Div
- 6.8.5 Aviation Readiness & Resource Analysis, Logistics Product Data Div
- 7.1F Command Operations and leadership Support , Office of Small Business Programs
- 7.2. Information Technology /Information Management Dept
- NAWCAD Lakehurst
- FRCE Cherry Point/FRCSW North Island/FRCSE Jacksonville
- NAWCTSD Orlando
- Army
- Air Force
- DLA
- DCMA
- OSD

Army, Air Force, DLA, DCMA, OSD: Extended Team Members

ACQUISITION RISK: NOT IMPLEMENTING CORRECT TECHNICAL DATA ACQUISITION

Issues:
- Contract Language does not adequately define TDP requirements, Product Data Delivery Requirements and TDP acceptance.
- Insufficient TDP Acquisition Training.
- No resources for TDP management positions.

Consequence:
- Buying unusable data.
- Waste of Funds
- Significant Rework of existing Parts/Data
- Readiness Impacts



Mitigations:
- **Develop Comprehensive Data Rights Management Policy**
- **Identify appropriate contract language**
- **Develop Training Curriculum/Certification for TDP LEM in conjunction with Engineering Requirements.**

PLM/PDM System

- The quest to find pertinent solutions to the specific problems encountered keeps returning to a PLM/PDM system for the following reasons:
  - Serves as the Single Source/access point for authoritative Product and Process design information as well as other authoritative product and process data/information
  - Establishes the authoritative source for product configuration management, configuration relationships and end item data and as the single access point to other authoritative data/information sources
  - Utilizes standardized/standards-based data information exchange capabilities between systems and/or technology environments at various sites
  - Facilitates data re-use within and across organizations as well as across products/commodities/sites

What are we doing?

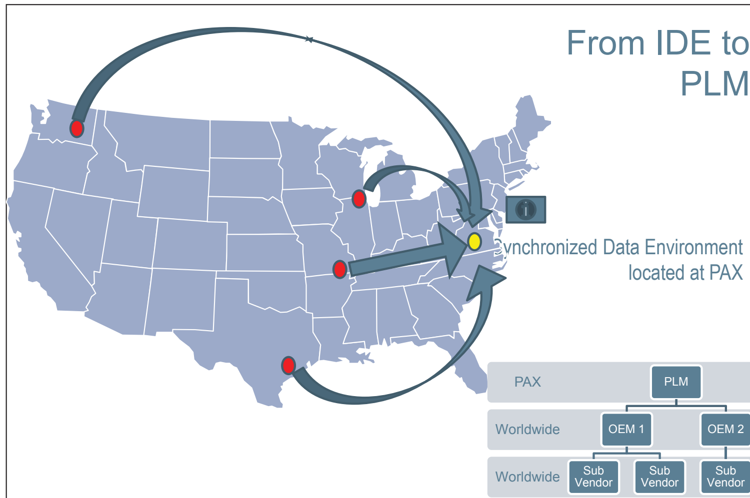
Initiating PLM Pilots/Projects

How can we gain more insight, buying power and process acceleration?

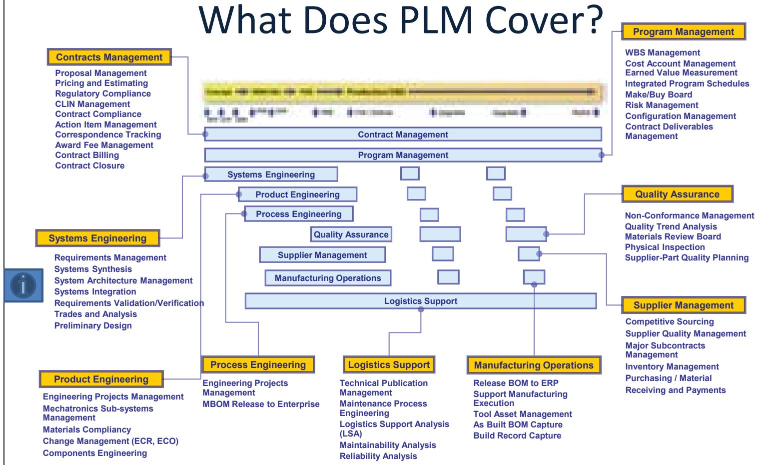
- IDE
  - Functions as a document management vault
  - Basic workflow
  - Does not drive process
  - Not intuitive to navigate
  - Cannot collaborate in real time
  - Only contains select, released data and documentation
- PLM
  - Enables dynamic interaction and process execution
    - Includes enterprise Workflow Management
    - Project management tools
  - Can use 3D graphics to aid navigation
  - Enables real-time collaboration in 3D context .
  - Enables full traceability from Requirements to Function to Logical definition to 3D Physical models, simulation and engineering analysis

PLM can bring fundamental transformation of our acquisition process

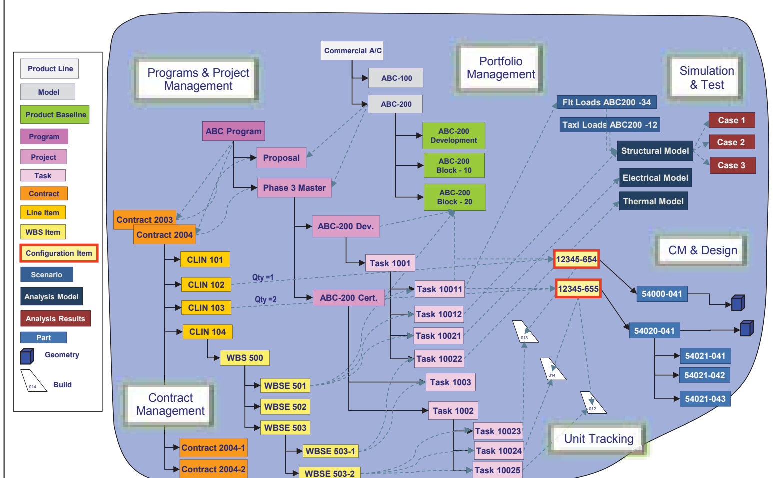
From IDE to PLM



What Does PLM Cover?



PLM Consolidates and Connects Data to the Product with relationships and context:



PLM Benefits

- PLM is "relational" environment that ties all of the program data to the product structure and vice versa
- By implementing a PLM suite on the government side we will have the ability to take a targeted approach at TDP acquisition.
- PLM accelerates communication between stakeholders and greatly reduces the time to develop and acquire the system. (Future Brief)
- PLM will allow the PMA to execute LSI functions and ensure implementation of open architecture.
- PLM will allow open and broad competition to rapidly add capability at lower cost for the life of the program.

Current Initiatives

- OSD /DoD Engineering Drawing & Modeling Working Group (DEDMWG)
  - Digital Depot Project focused on transition of Methods and Technology to MBE in DoD maintenance and manufacturing facilities.
  - MIL-STD-31000 Project to update the standard for 3D Modeling and MB Enterprise activities.
- OPTICAM Pilot Projects through OSD with National Center for Manufacturing Sciences (NCMS)
  - OptiCAM is a collection of COTS hardware and software applications tied together with custom integration. Its core differentiator is based on a 3-D Imaging system (VZX Imaging) developed by SIS, and industry leading PLM software (NX with Teamcenter Unified) from Siemens.
- NAVAIR
  - AIR-4.1.9 led effort to implement a pilot Model-Based Systems Engineering solution utilizing a IBM/ Dassault Systems software suite to manage/collaborate PMA activities in an enterprise context.
  - COMFRC Technology Investment Team working with FRCs to develop BCA for implementation of Industrial COI for FRCs and an enterprise PLM/PDM Solution; each FRC documenting requirements.

Integration of initiatives required to achieve holistic approach.

Problem Summary

- Evolution of technology has enabled programs to leverage 3D Models in acquisition
- Technology advances have out-paced update/development of ASME and DOD 3D Model standards and Service/SYSCOM policies, processes, tools, and infrastructure
- Multiple initiatives without a NAVAIR focal point and cohesive IPT approach
- Scope of 3D Model issues includes Acquisition, Quality Assurance, Configuration Management, repository management, and use.

2012 Model Based Enterprise Summit

The Digital Future Today

Effective 3D MBE with 3D PDF & 3D HTML

"Cost Effective 3D CAD & PLM data deployment" (aka FREE)

Chris Garcia – Paul Perreault
Anark Corporation

Introduction to Anark Corporation

Anark Corporation is a leader in 3D visualization software and solutions serving the manufacturing enterprise.

Our customers include the largest Aerospace & Defense manufacturers in the world and many of their tier-1 suppliers and defense customers.

Anark Corporation was founded in 1995 and is based in Boulder, Colorado. Venture backed.

Anark Key Customers

- US Army
- Lockheed Martin
- Boeing
- Honeywell
- Rockwell Collins
- Cubic Defense
- ElOp / Elbit
- Canadian Dept. Nat'l Defence
- General Dynamics
- Sikorsky Helicopters
- Textron
- Cessna
- Siemens
- L3 Communications
- B&W Y-12
- NASA
- Canadian Space Agency
- Northrop Grumman
- Atlantis Systems
- 20-20 Technologies
- Herman Miller
- Visteon
- Bretford
- DiSTI Corporation
- Best Buy
- Ericsson
- European Space Agency
- Naval Surface Warfare Center
- Krueger International
- KSSI
- CCAT
- JPL

3D PDF and 3D HTML Viewers Provide…

maximum flexibility **&** ***rapid customization***

3D HTML MBEs
for internal manufacturing

Inside the Firewall
(using html templates)

3D PDF MBEs
for external supplier

Outside the Firewall
(using 3D PDF templates)

3D PDF Viewer vs Proprietary CAD Viewers

FREE 3D PDF Viewer

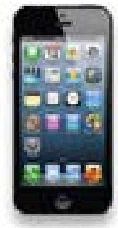
- Free to View
- No downloads or plug-ins
- Open Format
- Fully Functional
- on 98% - 99% Worlds Computers
- Approved for all DOD use

FREE Hardcoded Viewers

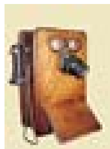
- Free to View
- Requires Downloads & plug-ins
- Proprietary Format
- Limited Functionality in Free Viewer

3D PDF / 3D HTML vs Proprietary CAD Viewers

3D PDF and 3D HTML can "HOST" a variety of user defined applications which are "Fit for Purpose"… *like your iPhone*

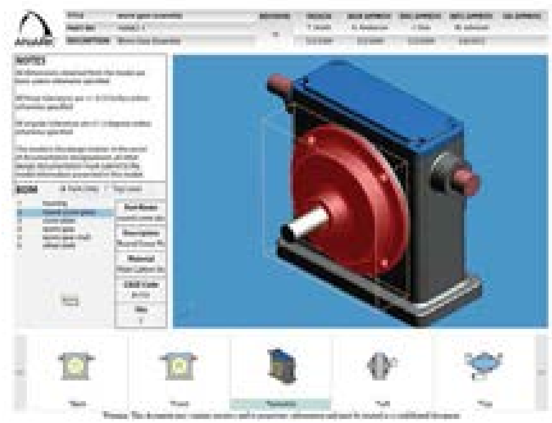


Proprietary CAD viewers only do what the CAD Vendors wants/allows them to do.

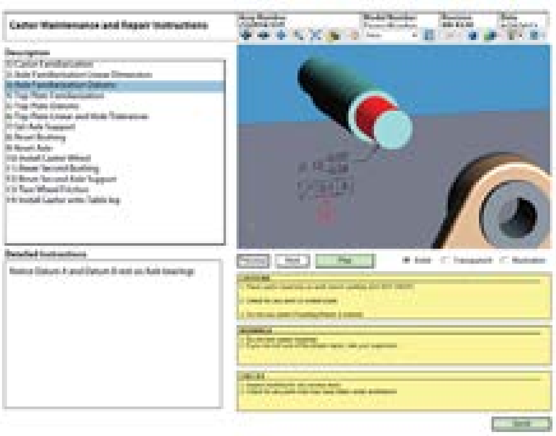


They both make phone calls, but which one is better for your business ?

Fit for Purpose 3D PDF MBOM



Fit for Purpose 3D PDF Work Instruction

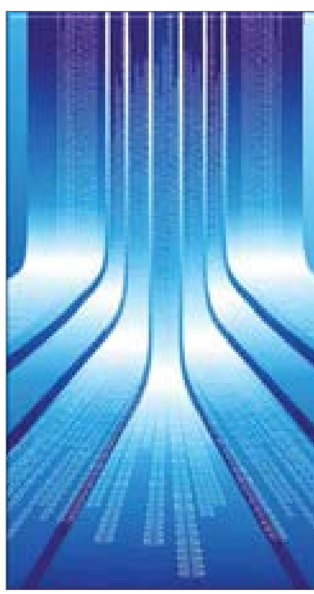


Fit for Purpose 3D PDF Inspection Document

Effective 3D MBE with 3D PDF and 3D HTML

3D PDF & 3D HTML are the best platforms for Deployment of 3D MBE:

- Flexible and Customizable
- "Fit for Purpose" vs "Hard Coded by the CAD Vendor"
- Based on Open Formats (3D PDF and 3D HTML)
- No Proprietary downloads required
- Fully functional and FREE to View & FREE to Deploy



2012 Model Based Enterprise Summit

The Digital Future Today

Exchange vs. Visualization vs. Communication

Enabling the Model Based Enterprise

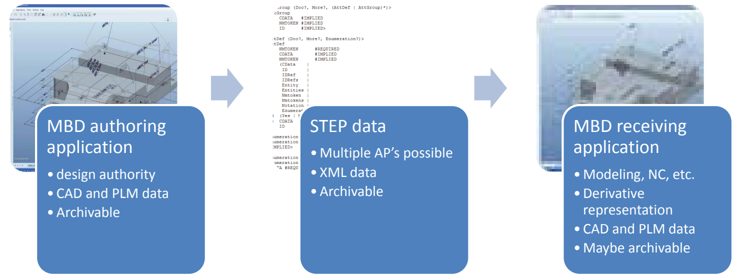
Claim #1

2012 MBE Summit

- There are three (3) principal MBE activities related to the use of MBD data:
  1. Exchange
  2. Visualization
  3. Communication

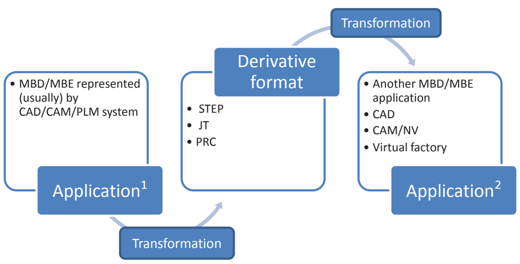
Data Exchange

2012 MBE Summit



Data Exchange Process

2012 MBE Summit



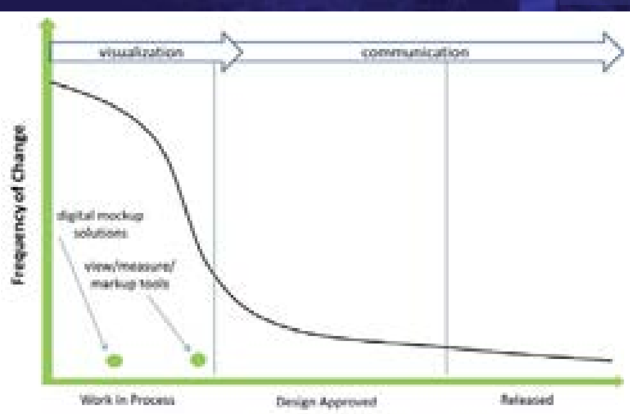
Claim #2

2012 MBE Summit

- Visualization is not the same as communication.

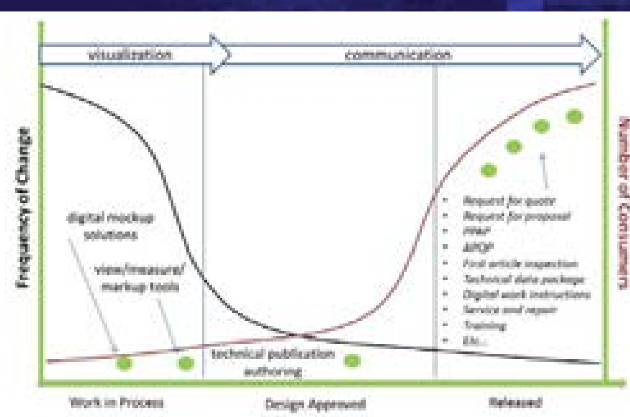
The Role of Visualization

2012 MBE Summit

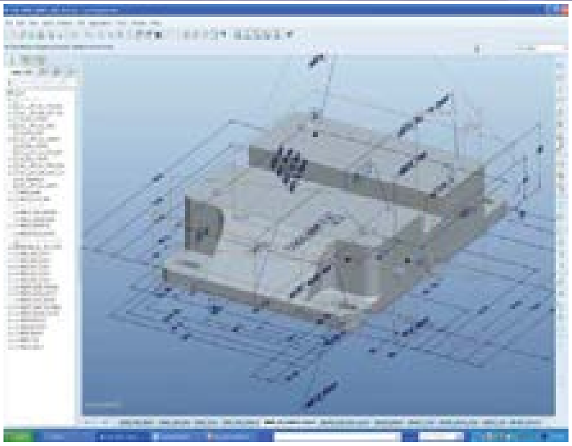


Lifecycle Functions Require More

2012 MBE Summit

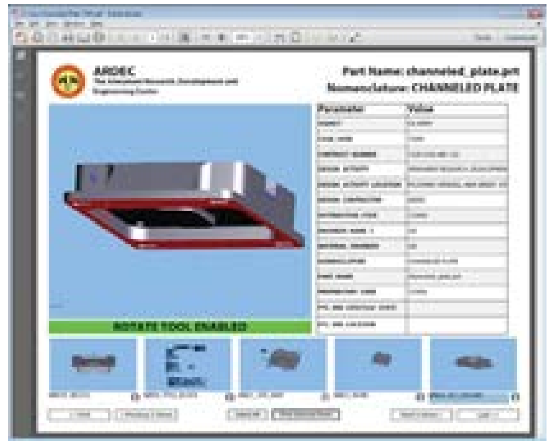


This is Visualization



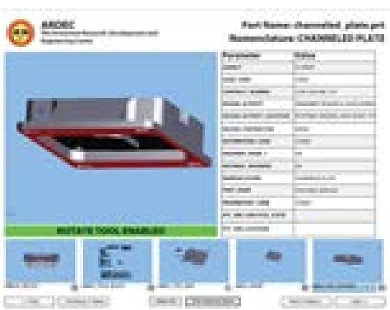
A rats nest of 3D Notes, Labels, Dimensions & GD&T

This is Communication



Fully consumable with Acrobat Reader in document and web forms

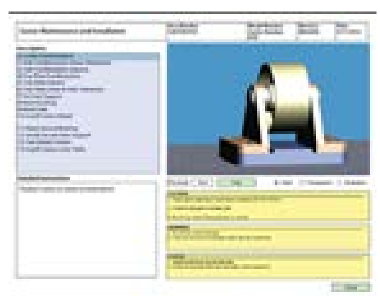
Engineering TDPs & RFQs



3D MBE TDP
(no 2D Drawings)

3D MBE RFQs / RFI
(in assembly context)

Manufacturing Processes



3D MBE
Shop Floor Assembly

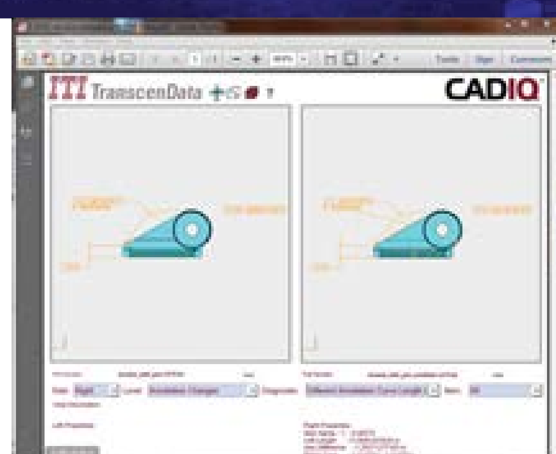
3D MBE
Welding Best Practices

Inspection and Field Service

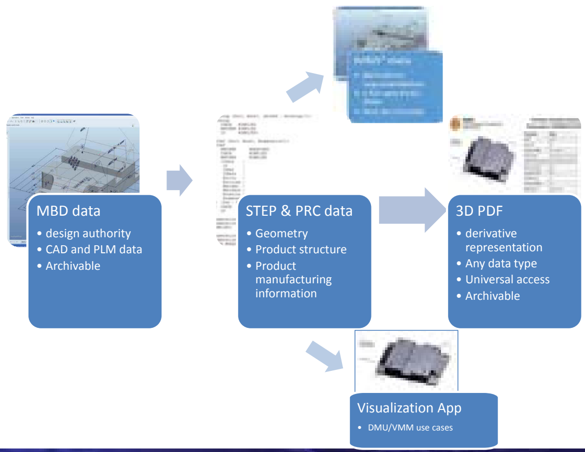
3D MBE
First Article Inspection

Field Repair
Instructions

Validation Matters



Claim #3 - PRC is the MBE Enabler



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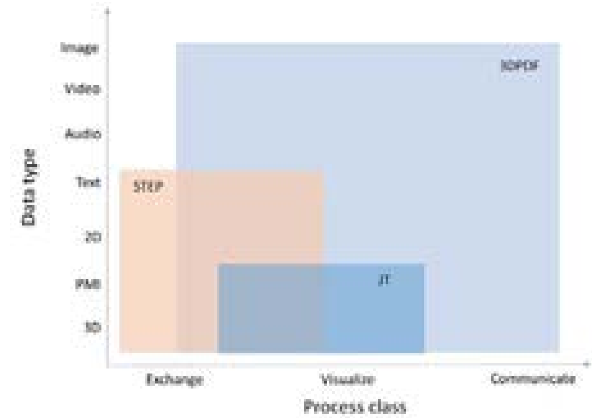
Format Domains



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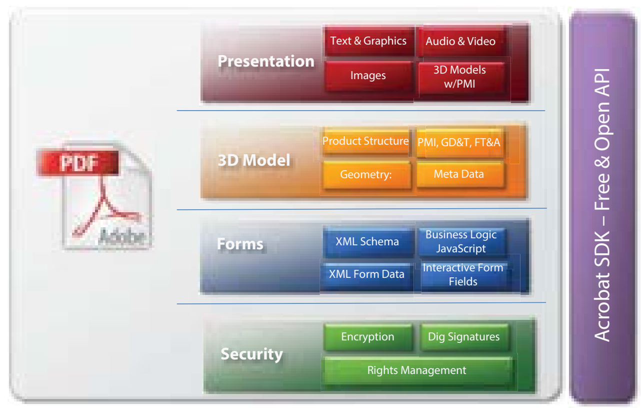
Future of Documents

- Yes, web sites can present composite data
- But…
  - Is bandwidth ubiquitous?
  - Who manages a 10,000 person portal?
  - Which browser?
  - How do you LOTAR web content?
  - What do you give the regulators/compliance authority?

2012 MBE Summit

ISO32000 is PDF…



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3D PDF Content Standards Status

- U3D
  - U3D developed by 3D Industry Forum (3dif.org)
  - U3D currently an ECMA standard (363) under TC43
  - U3D Edition 1 is specified by PDF/E (ISO 24517-1)
- PRC
  - Specification published by Adobe in 2008 (PDF 1.7)
  - Released to ISO TC 171 for standardization in 2008
  - Currently managed by ISO DIS 14739 under TC 171 SC 2
  - Establishes 3D standard to be referenced by PDF (ISO 32000) and others

2012 MBE Summit

Why 3D PDF Matters

1. Access
   – through Acrobat Reader
2. Multi-type
   – 3D, 2D, image, text, audio, video, enterprise data
3. Infrastructure
   – existing systems already support PDF
4. Neutrality
   – Investment protection
5. Value
   – Low investment threshold with high payback

What is the 3D PDF Consortium?

- A *community* dedicated to driving adoption of 3D PDF enabled solutions through:
  - Defining industry needs and priorities
  - Creating reference implementations and other resources
  - Providing input to the standards process
  - Raising awareness
- A worldwide, non-profit, member organization
- Open to all companies

Organization Details

- Law firm – Gesmer, Updegrove LLP
- Incorporated in Delaware, U.S. January 3, 2012
- Form of organization – 501(c)6 Trade Organization under IRS Tax code
- Filed with National Cooperative Research and Production Act (NCRPA) for anti-trust protection
- Bylaws, Articles of Incorporation, and incorporation certificate available
- Introduced in Japan (Feb) and Germany (June)
- All back office functions outsourced
- Managed by an Executive Director

What is the Consortium structure?

Board of Directors
- governance, recruiting

Executive Committee
- mission, vision, strategic direction

Industry Committee	Technical Committee	Communications Committee
- Define industry needs and priorities - Develop process-based use cases - Assign priorities to technical committee work	- Project goals and objectives - Project plans, participation, funding - Implementers forum - ISO technical submissions	- Web site - Publications - Solicit and propose case studies - Presentations - Blog/article submissions

Why is the Consortium important?

- Define priorities according to member needs
- Speak for the industry with a unified voice
- Source of subject matter expertise
- Illustrate market demand and availability
- Provide technical input to standards process
- Offer vendor-neutral advice to end user *and* ISV members on implementation strategies
- Resources such as reference implementations, implementer forum, white papers, templates, Javascript, libraries

JT
Powering the World of PLM

NIST MBE CONFERENCE 2012

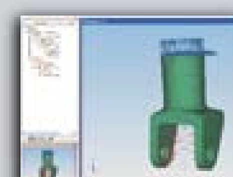
Utilizing Lightweight Geometry in Down Stream Applications

Dennis Keating – Federal Sales
John Cunneen – Federal Business Development

JT Presentation Topics

SIEMENS

Presentation Material	
00:00 – 00:05	1. Siemens PLM
00:05 – 00:20	JT 1. What is JT 2. JT Open 3. Applications utilizing JT



SIEMENS

Siemens Product Lifecycle Management

Siemens PLM

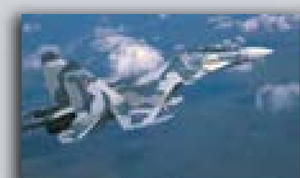
SIEMENS

What is JT ?

SIEMENS

Some Details

- JT is a binary format whose data model supports various representations of CAD geometry
- The representations can be stored in a JT file individually or together
- In addition to geometry, JT can display product structure, attributes, and product manufacturing information (PMI) like tolerances, dimensioning and surface properties.



SIEMENS

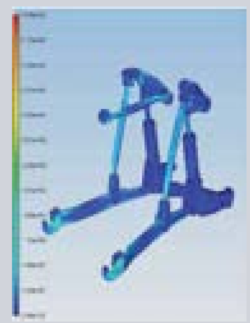
Geometry in a JT file

Geometry Primitives:

At one of the lowest levels, simple regular geometry such as cuboids, cylinders and pyramids are located in what is referred to as the bounding box.

BREP (Boundary Representation):

Offers the highest level of precision. BREP data is compressed using different algorithms and stored without loss. Two BREP representations are permitted: the traditional JT-BREP representation and XT-BREP, which is based on the Parasolid boundary representation.



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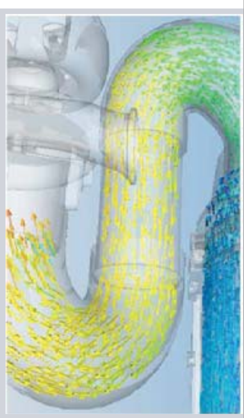
Geometry Continued…

Tessellated Geometry:

Representation of solids and surfaces as facets. Different levels of detail (LOD) can be defined within a JT file. A low LOD means a lower level of precision but a smaller volume of data, while a very high LOD means an almost exact geometry but a large volume of data. The JT file format is capable of storing an arbitrary number of faceted representations with varying LODs.

ULP (Ultra-Lightweight Precise):

The ULP format enables a lightweight, semi-precise representation of the 3D geometry. The level of precision that ULP offers is significantly higher than for tessellated geometry while the file size is significantly smaller (almost one hundredth the size of the original data). The ULP format makes it easier to share data across low bandwidth connections.



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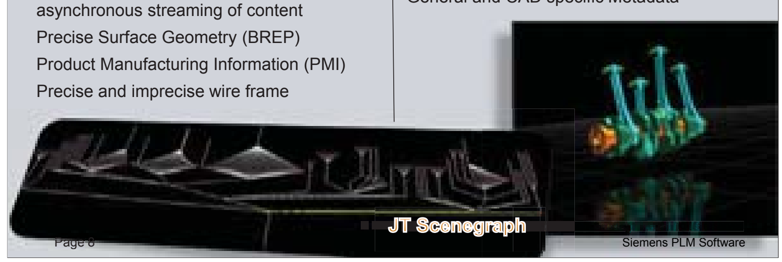
Additional JT File Content Summary

Scenegraph	Product Structure (BOM)
Facet information (Triangles) with Advanced Geometry Compression	Discrete purpose-built Levels of Detail
Lighting models	Extensible data paging architecture
Material data	CAE results visualization
Texture Maps	Wire harness information
Supports a variety of representation configurations and delivery methods including asynchronous streaming of content	PointSets and ImplicitPrimSets
Precise Surface Geometry (BREP)	Layers
Product Manufacturing Information (PMI)	Pixel/Vertex Shaders (Cg and OGLSL)
Precise and imprecise wire frame	General and CAD specific Metadata

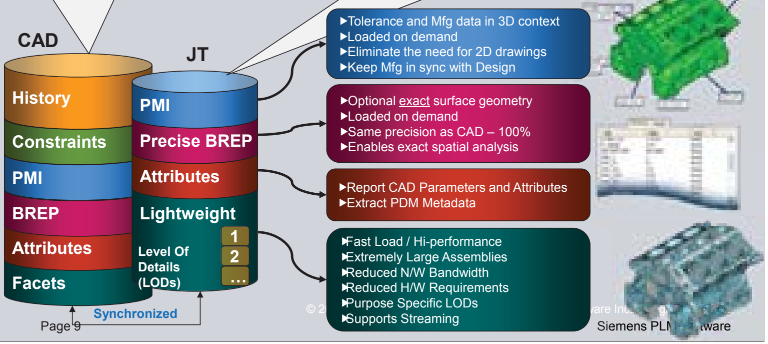


JT Extends CAD Data to Non-CAD Users

SIEMENS

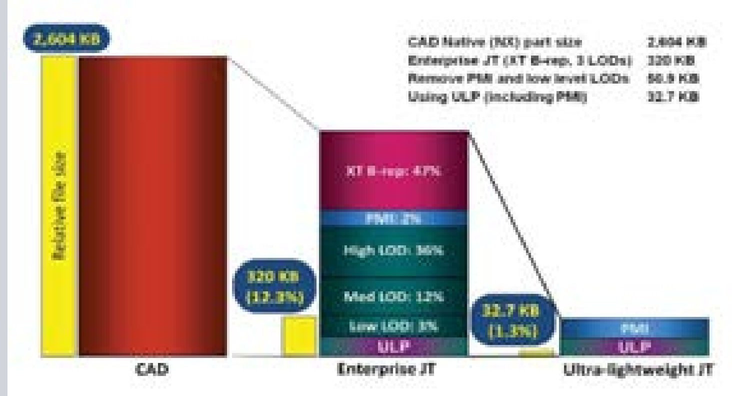
Master Design Definition
- Design Intent
- Feature Creation History
- Embedded Design Knowledge
- Intellectual Property

Synchronized Collaboration
- Common, Multi-Purpose File
- Only What's Required from CAD
- Supports All Major CAD Systems
- Puts 3D in the Hands of Non-CAD Users



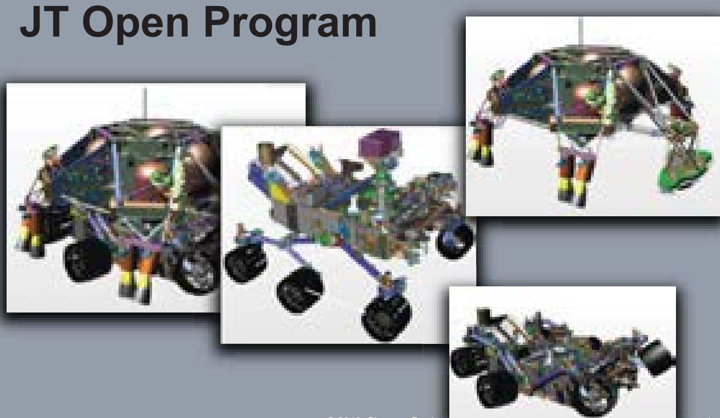
Example of file size benefits of JT

SIEMENS



SIEMENS

JT Open Program



JT Open Program
Objectives

SIEMENS

Purpose, Mission, Vision

- Maintain a community of software vendors, users and interested parties to share JT knowledge and influence the direction of JT technology
- Encourage widespread adoption of JT for 3D visualization, collaboration, interoperability and data archiving
- Provide open access to a JT-based visualization pipeline
- Establish JT as an open standard

JT Open Program
Membership Types

SIEMENS

Corporate
- Companies that use JT as the platform-of-choice for visualization and data sharing

Vendor
- software vendors that provide JT-enabled applications

Advocate
- Hardware, software and service suppliers that want to actively support the goals of the JT Open community without directly making use of JT technology

Academic
- Educational institutions that use the JT Open Toolkit for research and teaching.

JT Open Program
Community Interaction

SIEMENS

Management Review Board (MRB)

- Represents the business and management interests of the JT Open member community
- Manages the JT Open program
- Elected Chairperson
- All corporate member offered option to sit on the board
- Limited number of Vendor Members elected by the MRB
- Meets once per year with phone discussions as needed

Chairperson

BOSCH

Corporate MRB members

CATERPILLAR, DAIMLER, HONDA, GM, VOLKSWAGEN, BOEING, MAGNA, SIEMENS, DENSO, P&G

Vendor MRB members

Autodesk, RTT, PTC

JT Open Program
Community Interaction

SIEMENS

Technical Review Board (TRB)

- Represents the technical interests of the JT Open member community
- Elected Chairperson
- All corporate and vendor member offered option to sit on the board
- Meets twice per year
- Monthly phone discussions
- Create and manager technical working groups

Current working groups

- CAE
- Advanced Materials
- JT Validation
- Role based retrieval / JT repurpose
- Long Term Data Retention
- JT Best practices

JT Open Program
Growing Community of over 100 members

SIEMENS

JT as open, 3D format

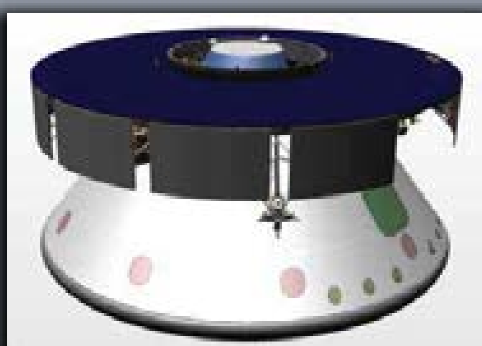
- No cost viewer, JT2Go
- Published file format (free to download)
- Developer toolkit available to all via JT Open program

JT as common language for PLM

- Visualization
- Interoperability
- Long term archiving

SIEMENS

JT ISO Standard Status



ISO JT … where JT fits in ISO

SIEMENS

JT Conformance with ISO TC 184 / SC 4 Standards

SIEMENS

TC 184/SC 4 manages several standards

Bringing JT through the ISO process

SIEMENS

Siemens PLM Software and ProSTEP iViP are working hand in hand to bring the JT Format through the ISO IS process

- ProSTEP iViP was instrumental in achieving ISO PAS 14306
- ProSTEP iViP sponsored the New Work Item Proposal that was accepted to deliver the JT specification as an International Standard

ISO JT PAS

JT is currently a PAS not an IS

The ISO JT PAS number is 14306

PAS 14306 is the JT file format reference for Version 8.1 JT

Siemens still owns JT

PAS 14306 includes the XT B-Rep format reference

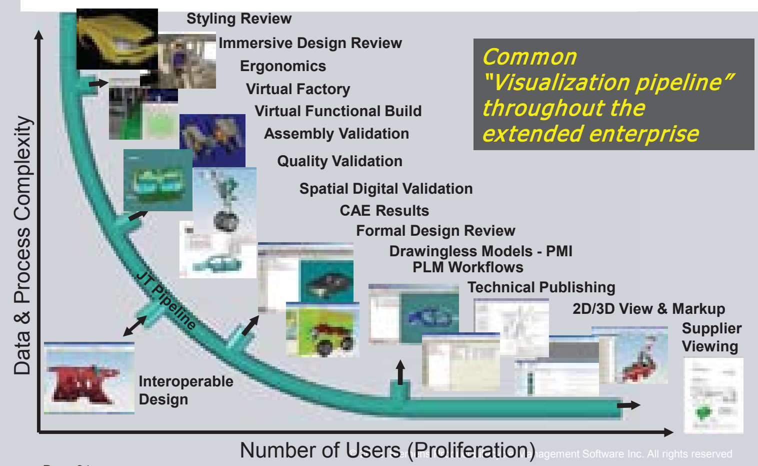
ISO / JT Status

Final Draft International Standard (FDIS) ballot agreed to in Sweden meetings, June 2012

- Resolution of ballot comments completed, agreement from national delegates to approve V1.0 ISO JT
  - Contains the V9.5 JT format definition
- New ballot has been initiated
- 2 month ballot will conclude December 2012

Examples, Benefits of using JT

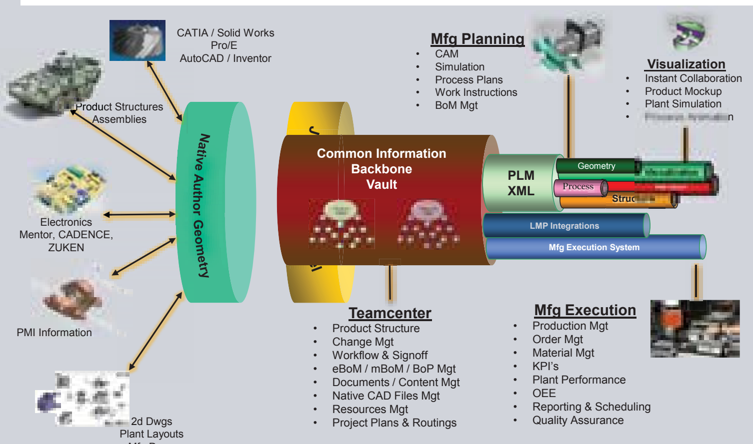
The JT Pipeline
Breadth & Depth to Support All Lifecycle Processes



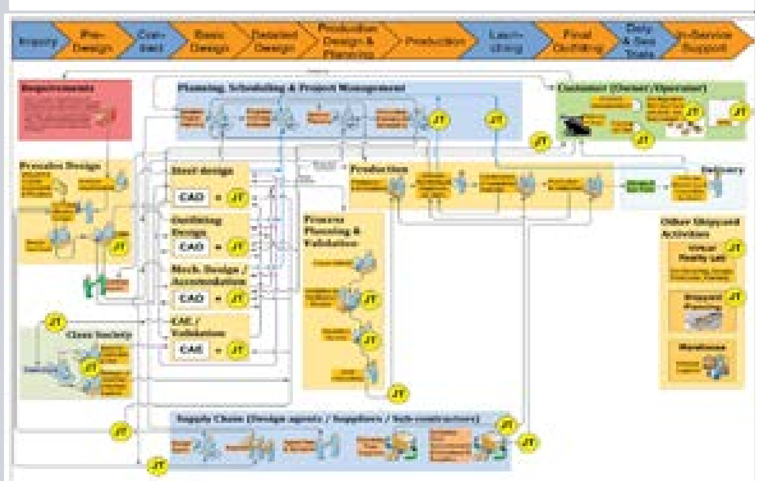
Common "Visualization pipeline" throughout the extended enterprise

Multi-Source Solution

Enables Data Neutral Environment Regardless of Native Source



Example of Leveraging JT data in Shipbuilding



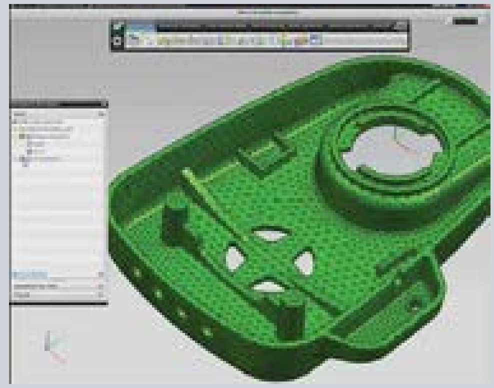
JT enabling multi-CAD assembly and integration

SIEMENS

Any size assembly for whole product context

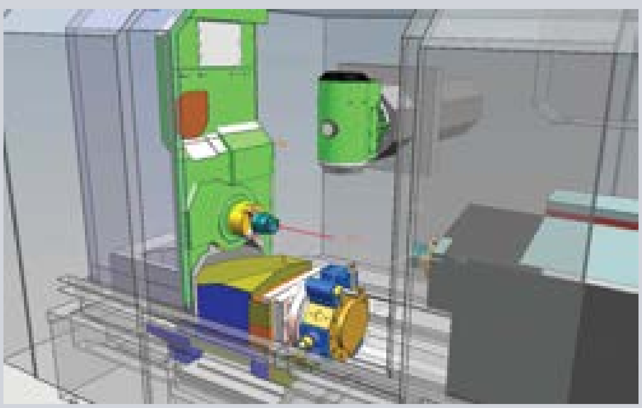
JT enabling Multi-CAD for complex CAE analysis

SIEMENS



JT enabling complex machining simulation

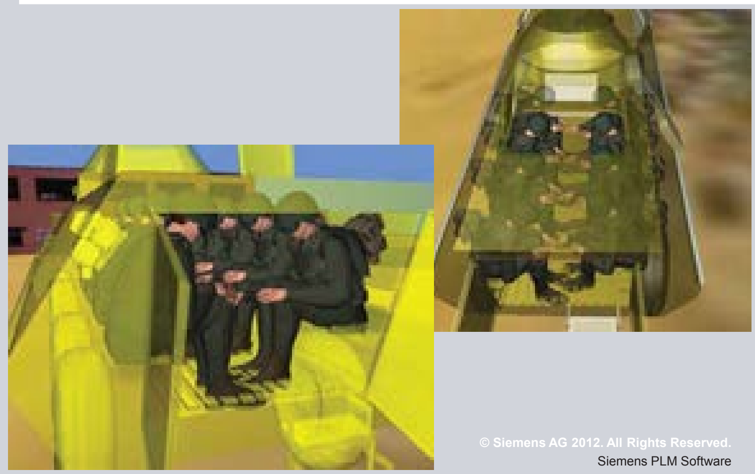
SIEMENS

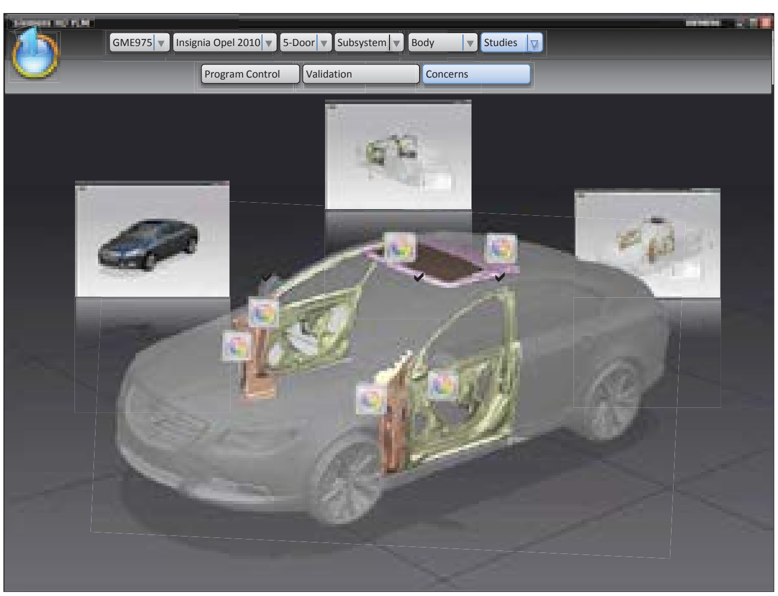


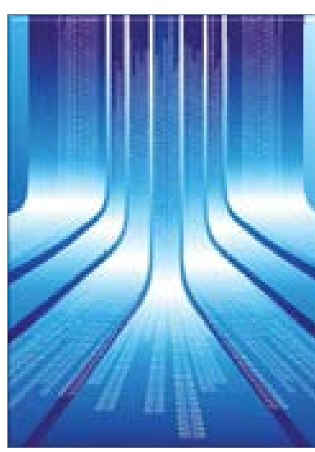
3D models courtesy of Mori Seiki

JT enabling immersive environments

SIEMENS







2012 Model Based Enterprise Summit

The Digital Future Today

Turning Light Weight Graphics into Meaningful 3D Experiences

Garth Coleman
VP Products & Strategy, 3DVIA

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2012 MBE Summit
knowledge
ideas
review
view
repair
use
examine
collaborate
share
COMMUNICATION
VISUALIZATION
operate
synchronous
assemble
transfer
asynchronous
markup
sell
explain
install
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3


2012 MBE Summit
COMMUNICATION
Extend, enrich, and augment the 3D MBE data into delivering real experiences about real products and how they work in the real world.
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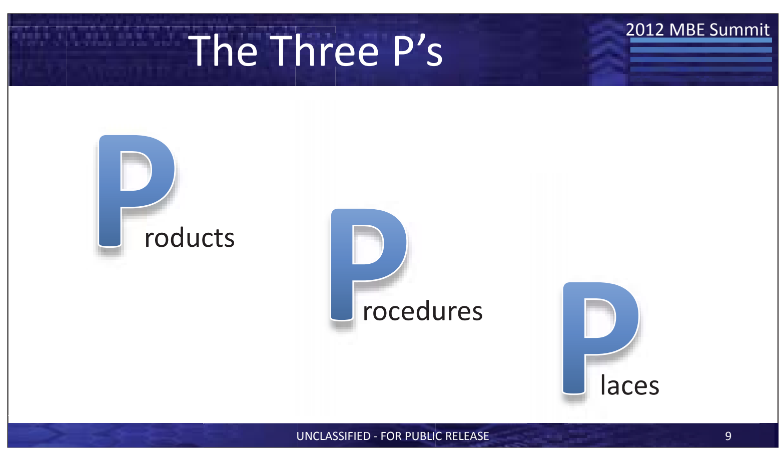
4


3D


2012 MBE Summit
THE 3D
COMMUNICATION
BRAND


3DVIA: The 3D Communication Brand
2012 MBE Summit
3DVIA
Composer Apps
3DVIA
Store Apps
3DVIA
Virtual Training Apps
3DVIA
Live Marketing Apps


The Three P's
2012 MBE Summit
Products
Procedures
Places
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9

JEITA 3D Experience

- JEITA
  - Japan Electronics and Information Technology Industries Association
- Member Companies
  - Omron, Canon, Konika-Minolta, Seiko Epson, Sony, Toshiba, Nikon, Panasonic, Hitachi, Fuji Xerox, Mitsubishi Electronics, and Ricoh
- Defining guidelines to promote 3D annotated models
  - Importance for effective communication about design requirements for downstream, non-CAD users
  - Precise communication without ambiguity or confusion

The Three P's

Products

Procedures

Places

Virtual Training 3D Experience

The Three P's

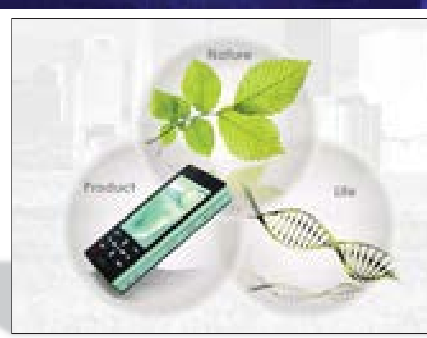
Products

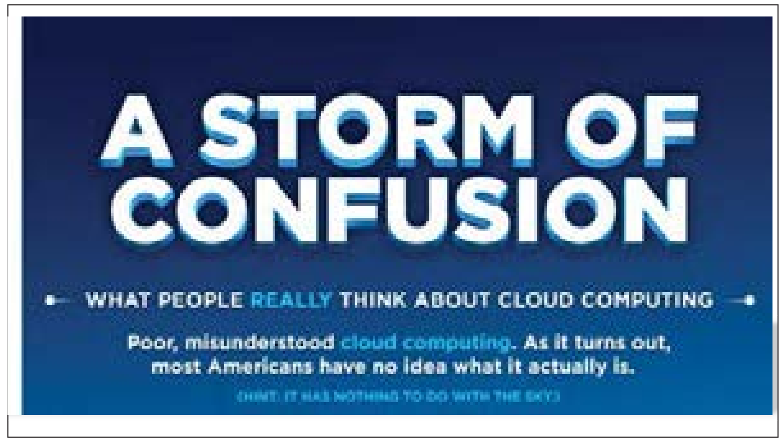
Procedures

Places

Orientation 3D Experience

A bigger picture…



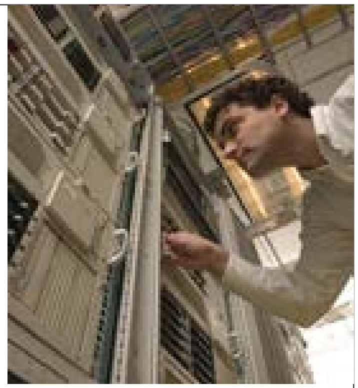

A STORM OF CONFUSION
WHAT PEOPLE REALLY THINK ABOUT CLOUD COMPUTING
Poor, misunderstood cloud computing. As it turns out, most Americans have no idea what it actually is.


Do you know what the cloud is?
54% say they hardly ever or never see the cloud...
...even though 95% use cloud services like Facebook, Gmail, and YouTube
Only 16% think of it as a network to store, access, and share data from internet-connected devices.
54%
95%
16%
32%


Weather (or not)
51%
29%


Have you ever faked it?
22%
14%
17%


What's in it for you?
40%
35%
35% like that the cloud allows them to interact with people they'd rather not see in person



2012 MBE Summit

Miscommunications about the Cloud

"It's Not Safe"

"Not for Enterprise"

"B2C, not B2B"

Truth about the Cloud

Safe & Secure

Great for Small Business

Enterprise use is growing fast!

Employees will use anyway

2012 MBE Summit

Enterprise Business & The Cloud

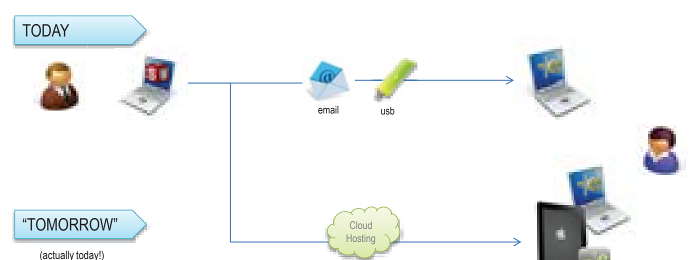
amazon web services

box

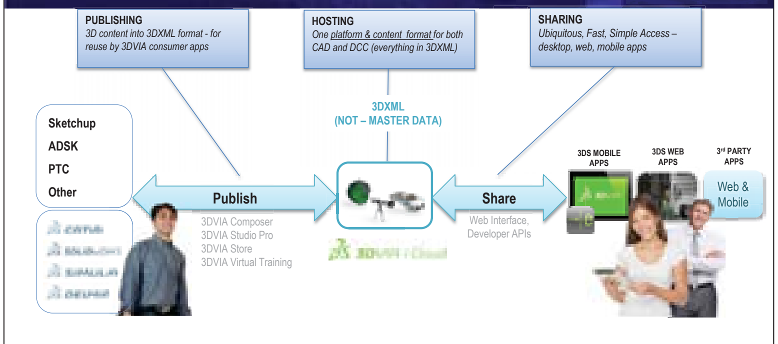
salesforce.com

2012 MBE Summit

Content Sharing is Moving to the Cloud



3DVIA Cloud Workflow



2012 MBE Summit

Then: Now: Next:

Access Experience

MEP: Connecting and Assisting U.S. Manufacturers with MBE-Based Approaches to Defense Business Opportunities

MAKE IT IN AMERICA

David Stieren
Manager, Technology Acceleration
and Technical Principal, Supplier Development and Scouting
National Institute of Standards and Technology (NIST)
Manufacturing Extension Partnership (MEP)
david.stieren@nist.gov

THE MEP PROGRAM

MEP • MANUFACTURING EXTENSION PARTNERSHIP

- **MISSION – "To act as a strategic advisor to promote business growth and connect manufacturers to public and private resources essential for increased competitiveness and profitability. "**

- 60 centers with >370 field locations
  - 501 c3 non-profits, univ-based, embedded in state gov agencies
  - System wide, Non-Federal staff is > 1,300
  - Contract with over 2,300 third party service providers
- MEP System budget ~ $300M – Federal / State / Industry
  - 1/3 Federal ($128.4M FY12), 2/3 State and Industry (fees for services)
- MEP Program and Center performance measured per impact of services on client firms.
  - ~34,000 manufacturers served, >10,000 projects conducted annually *
  - Aggregate impacts include $8.2B increased/retained sales; $1.9B new client investment; $1.3B cost savings; 60,497 jobs created/retained *

*Based on Client Reported Data in 2011

www.nist.gov/mep
– or –
800-MEP-4MFG

MEP Strategies

- **Increasing manufacturers' capacity for innovation, resulting in profitable sales growth is MEP's overarching strategy.**
- Assistance framework capitalizes on cost-reduction strategies – historically MEP's core services – to enhance productivity, free up capacity for business growth.
- **Innovation** is stressed as the basis of business growth.
- Business growth focuses on *new sales, new markets, and/or new products.*
- 5 key MEP strategies for increasing manufacturers' profitability:

✓**Continuous Improvement**
✓**Technology Acceleration**
✓**Supplier Development**
✓**Sustainability**
✓**Workforce**

Technology-Based Supplier Development

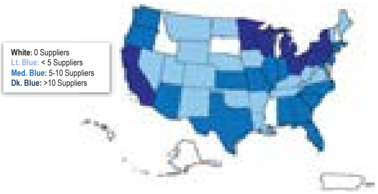
- **FOCUS**: Supply chain development for current or new market spaces to capitalize on opportunities to differentiate companies using tech-based approaches

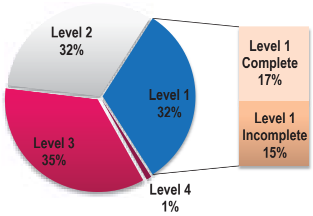
- *Example areas of emphasis*
  - Integration of new processing techniques / technologies (tooling, capital equipment, metrology/sensors) into factory systems
  - Implementation of automation technologies / approaches into operations
  - Implementation of advanced engineering practices / integration of engineering with production & other manufacturing execution functions
    - ✓ Working with DOD to implement **model-based enterprise (MBE)** approaches throughout supply base
    - ✓ Including access to high-performance computing/modeling and simulation resources

MEP Assistance to U.S. Manufacturers for DOD Supply Base Transition to MBE-Based Operations

2009 MBE Supplier Capability Assessment

- MBE Assessment Team: ARL, NIST MEP, BAE Systems, MEP Centers
- Capabilities assessment performed for 445 military ground vehicle suppliers





- MBE Analysis Metric
- Analysis & Results: 2/3 of participating suppliers are ready to operate in an MBE environment

More information on this assessment can be found in its report, located at www.model-based-enterprise.com

Raising Supplier MBE Literacy:

MBE Education and Training Summits, 2010-2011

- Raise awareness of MBE in suppliers and increase supplier confidence in MBE
- Help current/existing DOD, and potential new DOD suppliers develop a business case for MBE implementation at their locations
- Begin to establish advanced, MBE capable suppliers

The MBE Website, Launched 2010

www.model-based-enterprise.org

- Developed by partnership that included Army, NIST MEP, Catalyst Connection (SW PA MEP Center)
- Designed to house info, resources to keep defense suppliers informed of MBE implementation efforts, development opportunities, events, guidance, etc.
- Includes MBE Assessment tool for manufacturers to conduct self-assessment of MBE capabilities

2012 MEP Industrial Assessment of 3D TDP Format, Tool

- Connect w/supplier company reps responsible for receiving tech data and models, handling quotes/estimation, working w/models related to design/production
- Drive target decision makers to view online demo/example of 3D TDP tool, video instructions to describe key features, usage of 3D TDP
- Gather Feedback from ARDEC supplier base after review and demo of 3D TDP tool
- Identify which features of 3D TDP are most useful, determine if anything important is missing that's needed to make a part
- Learn how 3D TDP will be used at supplier companies
- Continue to prepare supplier base for roll-out of 3D TDP

2012 3D TDP Assessment Results

- Outreach to **309 contact targets** in Army supply chain
  - ✓ **46 completed surveys -** 15% response rate
- All respondents **reviewed 3D TDP** prior to completing assessment
- Nearly entire sample performs one or more of the following functions:
  - Receiving technical data and models
  - Handling quotes and estimation
  - Working with models related to design

2012 3D TDP Assessment Results

- **89% of respondents** said 3D TDP contains all info needed to make a part
- The **"most liked" feature** of 3D TDP was **3D rotation and zoom**
- **Imbedded CAD and .STP files (91%)** and **Fully-annotated 3D viewable (87%)** were rated as 2 "most useful" features of the 3D TDP
- **89%** feel **3D TDP is better or much better** than 2D drawings for conveying design intent.
- **84%** of respondents plan to use 3D TDP in their **manufacturing planning**
- **76%** of respondents plan to use 3D TDP to develop their **CAM program**
- **74%** of respondents plan to use 3D TDP as **instrument to convey intent for shop floor**

Next Steps for MEP and MBE

MBE Becoming Real for U.S. Manufacturers - at the Point of Supplier Implementation

2013 Upgrade to MBE Website www.model-based-enterprise.org

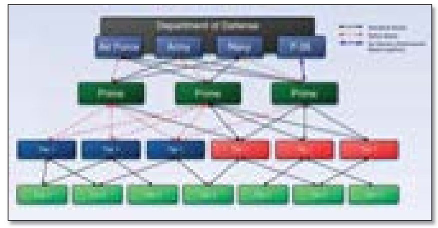
- Continue partnership among Army ARDEC, NIST MEP, Catalyst Connection
- Include access to sample 3D TDP formats, tools, etc.
- Continue to include MBE Assessment tools, other MBE resource info, including links/connections to nationwide MEP System as assistance resources
- Provide access / links to MBE-related business opportunities – RFPs, BAAs, etc., that incorporate MBE-based approaches
- Provide MBE success stories, business cases
- News feeds, blogs, YouTube videos, social media apps and connections
- Up-to-date MBE Calendar
- NIST MEP Contacts:
  - ✓ Dave Stieren or Jenna Giles, jenna.giles@nist.gov

CSI Update

December 12, 2012
MBE TDP Summit
Gaithersburg, MC
John Gray / ITI

Strategic Thrust: RISB (Responsive Industrial Supply Base)

Problem Statement

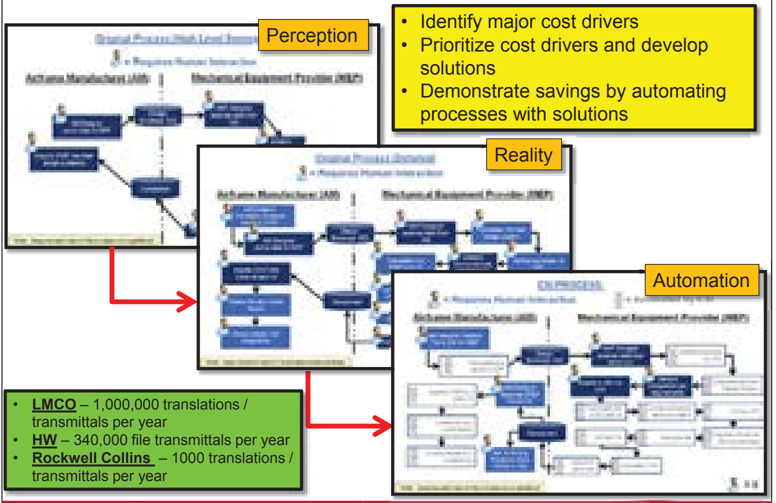


- Inefficient technical data exchange between suppliers and customers increase costs for weapon systems
  - These costs seem **small at the instance level**, *but* accumulate to be a **significant weapon system cost**
  - Up to **4,000 models exchanged per month between a prime & their 1st tier**
- Costs are typically associated with **manual re-entry**, **reformatting of data** and **corrections of errors** injected by manual processing

Contract/Project Manager: PDES, Inc./ATI
Technical Lead: International TechneGroup Incorporated (ITI)
Industry Prime: Lockheed Martin
Industry Suppliers: Rockwell Collins & Honeywell

Phase 1 (original scope) – scenario

- Identify major cost drivers
- Prioritize cost drivers and develop solutions
- Demonstrate savings by automating processes with solutions



- LMCO – 1,000,000 translations / transmittals per year
- HW – 340,000 file transmittals per year
- Rockwell Collins – 1000 translations / transmittals per year

Accelerating MBE deployment – CSI contract addendums

Benefits
- Potentially enables a more efficient transition from drawing to model-based Definition
- May provide an alternate path to translation of featured models

Honeywell – Draw-to-PMI (MBD Generator)
Automation to merge associative 2D GD&T into the model and produce associative 3D PMI

Rockwell Collins – Producibility
Detects and resolves model issues in design for manufacturability

Benefits
- Eliminate un-producible features – better quality model
- Identify potential problems; collaboratively resolve with supply chain
- Reduce rework or scrap due to design escapes
- Eliminate model ambiguity that otherwise drives design revision
- Improve model translation success & designer productivity

Benefits
- Support MBE approach - maintain the digital thread
- Streamlines design to manufacturing process within supply chain
- Increased product quality due to higher confidence in data handoff
- Reduce scrap due to conversion/interpretation issues
- Reduce cycle time through automation of conversion & validation

Lockheed Martin – 3D PMI Translation
Translation of associative 3D models and 3D PMI between dissimilar CAD environments

Rockwell Collins – 3D ECO Documentation
Document model changes in a 3D format that greatly improves communication in the MBE

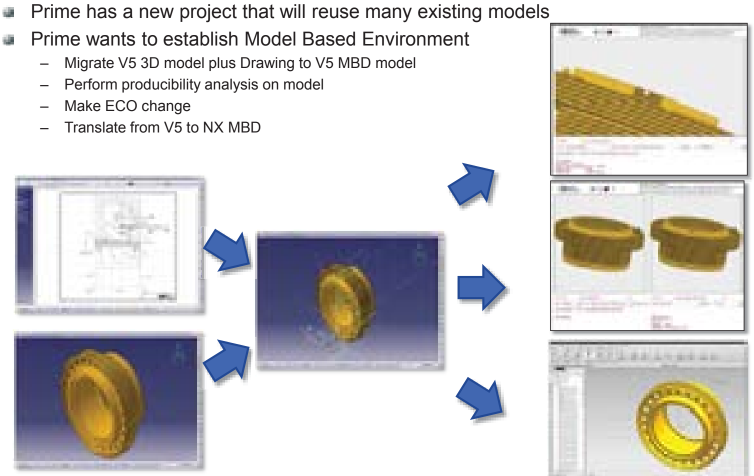
Benefits
- Eliminates need for drawing-based documentation of design change
- Improves designer productivity (reduces time) in model/drawing revision
- Improves quality; model is explicit master; fully represents/documents change
- Necessary step toward full model based design (eliminating drawing)

Demonstration Part Description

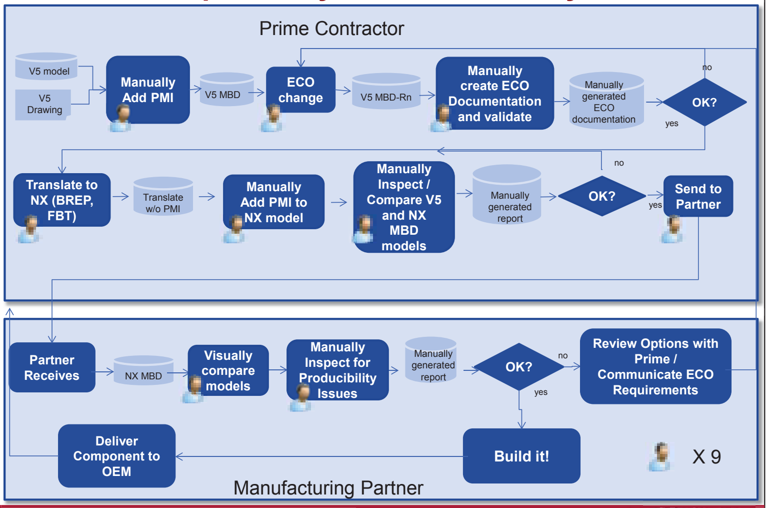
- 350 features
- 4 MB
- 1.8 meters in diameter
- .8 meters in depth

Demonstration Scenario

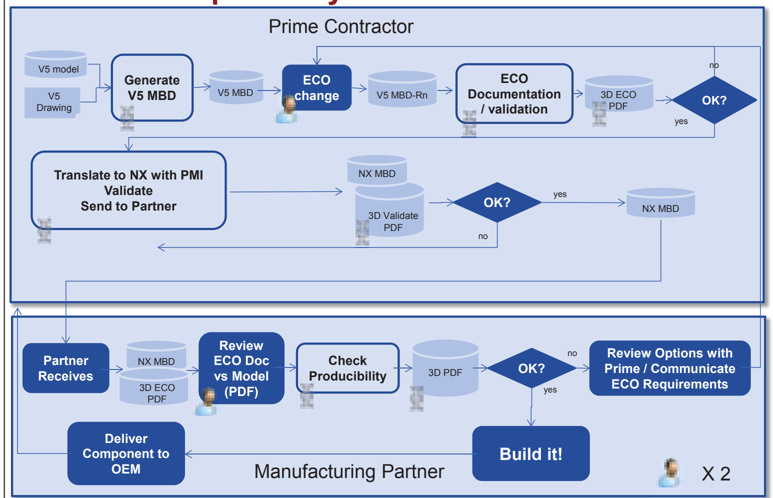
- Prime has a new project that will reuse many existing models
- Prime wants to establish Model Based Environment
  - Migrate V5 3D model plus Drawing to V5 MBD model
  - Perform producibility analysis on model
  - Make ECO change
  - Translate from V5 to NX MBD



MBE Interoperability Scenario - Today



MBE Interoperability Scenario - CSI Automation



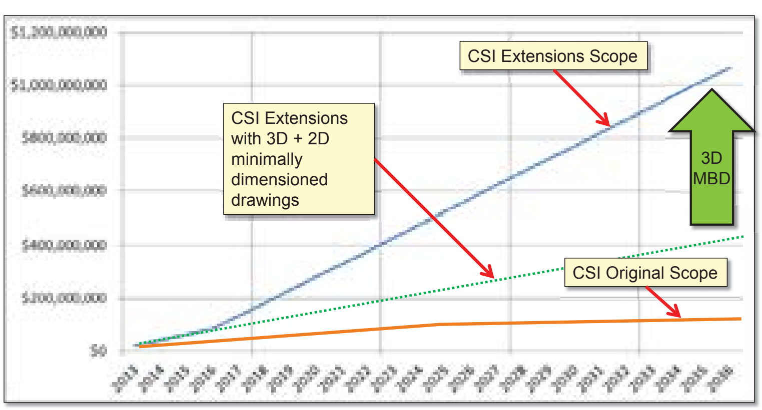
Key activities performed to develop ROI

- **Honeywell**
  - Used automation to create MBD from 3D model and 2D associative drawing
  - Recorded time to manually refine the results
  - Recorded time to manually merge the 3D model and the 2D associative drawing
- **Rockwell Collins**
  - Processed 300 recently released models from various programs (commercial and defense) using Producibility check
  - 12% found with producibility issues
  - 5 models selected to investigate in detail (is the problem significant from supplier perspective and how much time is needed to correct problem)
- **Lockheed**
  - Met with Progressive Machining and HM Dunn fabrication to discuss 3D ECO process
  - Determined processes almost identical and were both labor intensive and error prone
  - Savings in documentation generation, quotation and NC program change processes
- **ITI**
  - Merged findings from each partner
  - Applied findings on a representative large DoD program
  - Estimated overall program impact

Potential Estimated CSI Savings for Large DoD Project

Company	Relative task magnitude	Recurring				One-Time
		Day-to-day			Future	
		ECO	Trans/Auto	Producibility	MBD Xlate	Generate MBD
Prime	100%	$3,300,000	$500,000	$2,200,000	$8,200,000	$8,200,000
Design Partner 1	75%	$2,475,000	$375,000	$1,650,000	$6,150,000	$6,150,000
Design Partner 2	65%	$2,145,000	$325,000	$1,430,000	$5,330,000	$5,330,000
Design Partner 3	50%	$1,650,000	$250,000	$1,100,000	$4,100,000	$4,100,000
Subsystem Supplier 1	25%	$825,000	$125,000	$550,000	$2,050,000	$2,050,000
Subsystem Supplier 2	10%	$330,000	$50,000	$220,000	$820,000	$820,000
Subsystem Supplier 3	10%	$330,000	$50,000	$220,000	$820,000	$820,000
Manufacturing Supplier 1	1%	$33,000	$5,000	$22,000	$82,000	$82,000
Manufacturing Supplier 2	0.2%	$6,600	$1,000	$4,400	$16,400	$16,400
Manufacturing Supplier 3	0.1%	$3,300	$500	$2,200	$8,200	$8,200
	Total	$11,097,900	$1,681,500	$7,398,600	$27,576,600	$27,576,600
			Recurring annual savings - near term	$20,178,000		
				Recurring annual savings - near term plus future	$47,754,600	
					Non-recurring savings	$27,576,600

Cumulative estimated savings for a representative large DoD Project over lifetime



Technology Commercialization

Project Phase	Technology Focus	ITI Product			
		CADfix	CADIQ	Proficiency	DEXcenter
CSI original scope	Simplification	1. Initial commercial release December 2011 2. Further refinement pending customer inputs			1. Available as part of CADfix translations based on Wizard 2. Unique workflows available as requested by customers
CSI original scope	IT report	1. Initial commercial release December 2011			1. Available as part of CADfix translations based on Wizard 2. Unique workflows available as requested by customers
CSI original scope	CSI point extraction / compare				1. Pending customer inputs
CSI original scope	CSI framework / automation				1. Initial commercial release September 2012
CSI extensions	CFR - Producibility		1. Initial release September 2012 2. Updates across CAD systems February 2013		1. Initial commercial release September 2012
CSI extensions	3D ECO		1. Initial release September 2012 2. Updates across CAD systems February 2013		1. Initial commercial release September 2012
CSI extensions	Draw to PMI (MBD Generator)			1. Pending customer inputs	1. Pending customer inputs
CSI extensions	MBD translation			1. Pending customer inputs	1. Pending customer inputs
CSI extensions	CSI framework / automation				1. Initial commercial release September 2012

Honeywell – Comparing MBD scenario with and without CSI

Approach without CSI:

	Manually add PMI to 3D model in source CAD system	Translate to target system using feature based translator	Manually add PMI to 3D model in new CAD system
Sample model results:	10 hrs.	.1 hrs.	10 hrs.

20.1 hrs. labor

Approach with CSI:

	Source Model(s)	Run "Generate MBD"	Manual clean-up	Run "Translate MDB"	Manual clean-up	Target Model(s)
Sample model results:		.02 hrs.	1.7 hrs.	.02 hrs.	1.7 hrs.	

3.44 hrs. labor

Typical program impact for 1000 parts

Current process (without CSI):
Time to generate MBD + Time to translate/remaster MBD + Time to refine MBD

10 hrs + .1 hrs + 10 hrs = **20.1 hours**

Proposed process (with CSI):
Time to generate MBD + Time to refine MBD + Time to translate MBD + Time to refine MBD

.02 hrs + 1.7 hrs + .02 hrs + 1.7 hrs = **3.44 hours**

Savings per change:
Current process hours – Proposed process hours

20.1 hrs – 3.44 hrs = **16.66 hours**

Annual savings:

Number of parts	Labor saved per part	Annual savings based on $100/hour
1000	16.66	$1,666,000

Rockwell Collins – Producibility analysis savings based on when problem is first identified

Product Development (in design)	Supply Chain (in fabrication)	Manufacturing Build (in assembly)	Customer (in service)
CPR used for producibility analysis during design process a) Designer identifies and eliminates issue or b) Checker identifies issue during release process	Without CPR analysis – supplier determines there is issue and a) Adjusts model on own or b) Initiates change request (ECO required)	Without CPR or Supplier initiated change – issue discovered during unit assembly or test and a) Requires TTR, ECO and material disposition	Without CPR or Mfg initiated change – issue discovered by customer or in service and a) Requires TTR, ECO, material disposition and possibly a Service Bulletin b) Customer satisfaction, warranty, etc. affected
• 1-2 hours to resolve finding when identified during in-process design • May require more time and possibly affect program schedule if identified during the release process Time to Resolve: 1-2 hours Relative Total Cost:$100's	• Hours or days to resolve finding when supplier engages Rockwell Collins • Part conformance risk (AS9102 concern) • May affect delivery and build schedule • Possible no-bid from qualified supplier • Increased part cost – complex tooling / process of low-yield fabrication • Cost to complete ECO Time to Resolve: Hours/Days Relative Total Cost: $1K's	• Hours or days to resolve finding – possibly weeks if TTR required • Affects build schedule and may affect overall program schedule • Possible contract penalties for delivery misses • Increased production cost – TTR, scrap or rework, material disposition, etc. • Cost to complete ECO Time to Resolve: Days Relative Total Cost: $10K's	• Days or weeks to resolve finding – possibly months for warranty or service bulletin to be completed • May cause system failure/repair • Affects customer program • Possible contract penalties, warranty costs, SB costs, fleet costs, etc. • Increased repair cost – TTR, scrap and rework, material disposition, field service, fleet down-time, etc. • Cost to complete ECO / SB • Reduced customer satisfaction Time to Resolve: Weeks/Months Relative Total Cost: $100K's

Process Step#1: "Document change to 3D model"

Document change to 3D model → Quotation for ECO → Incorporate change into NC program(s)

Approach without CSI:

	Update CATIA model	Capture screen shots and paste into Power-Point	Release change
Sample model results:	NA	.25 hrs.	NA

.25 hrs. labor

Approach with CSI:

	Update CATIA model	Run "3D ECO"	Release change
Sample model results:	NA	.02 hrs.	NA

.02 hrs. labor

Process Step#2: "Quotation for ECO"

Document change to 3D model → Quotation for ECO → Incorporate change into NC program(s)

Approach without CSI:

	RFQ received by supplier	Supplier downloads model, ECO PDF and PowerPoint	Supplier creates assembly and adds original model and revised model to assembly	Supplier uses colors, display options and pan/ zoom/ rotate functions to study overlay	Supplier notes changes and reviews ECO PDF and PowerPoint to finalize scope of change	Supplier uses scope of change (NC programs, Tools, CCMM programs, and check fixtures) to provide cost of change to LMCO	LMCO dispositions the change and notifies the supplier
Simple/ Medium Complexity Models	NA	NA	NA	2.1 hrs.	NA	NA	NA
Complex Models	NA	NA	NA	20 hrs.	NA	NA	NA

Simple/Medium: 2.1 hrs. labor / Complex: 20 hrs. labor

Approach with CSI:

	RFQ received by supplier	Supplier downloads model, ECO PDF and 3D ECO	Supplier creates assembly and adds original model and revised model to assembly	Supplier opens 3D ECO and moves to specific areas in the model as specified in the 3D ECO	Supplier notes changes and reviews ECO PDF and 3D ECO to finalize scope of change	Supplier uses scope of change (NC programs, Tools, CCMM programs, and check fixtures) to provide cost of change to LMCO	LMCO dispositions the change and notifies the supplier
Simple/ Medium Complexity Models	NA	NA	NA	1.7 hrs.	NA	NA	NA
Complex Models	NA	NA	NA	15 hrs.	NA	NA	NA

Simple/Medium: 1.7 hrs. labor / Complex: 15 hrs. labor

Model Complexity:
Simple 1-10 features
Medium 11-30 features
Complex >30 features

Process Step#3: "Incorporate change into NC program(s)"

Document change to 3D model → Quotation for ECO → Incorporate change into NC program(s)

Approach without CSI:

	Change authorization received by supplier and downloads models, PDF's and PowerPoint	Supplier uses colors, display options and pan/ zoom/ rotate functions to study overlay	Supplier identifies change(s) and modifies NC program(s)	Supplier validates NC program changes using Vericut	Other changes? (Y: Supplier uses colors, display options and pan/ zoom/ rotate functions to study overlay; N: Supplier modifies tools, CCMM programs and check fixtures as req'd)	
Simple/ Medium Complexity Models	NA	8 hrs.	NA.	NA	4 hrs. (20% first pass)	NA
Complex Models	NA	20 hrs.	NA	NA	40 hrs. (20% first pass)	NA

Simple/Medium: 8.8 hrs. labor / Complex: 28 hrs. labor

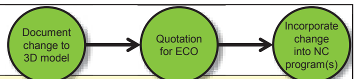
Approach with CSI:

	Change authorization received by supplier and downloads models, PDF's and PowerPoint	Supplier opens 3D ECO and moves to specific areas in the model as specified in the 3D ECO	Supplier identifies change(s) and modifies NC program(s)	Supplier validates NC program changes using Vericut	Other changes? (Y: Supplier uses colors, display options and pan/ zoom/ rotate functions to study overlay; N: Supplier modifies tools, CCMM programs and check fixtures as req'd)	
Simple/ Medium Complexity Models	NA	6 hrs.	NA	NA	3 hrs. (20% first pass)	NA
Complex Models	NA	15 hrs.	NA	NA	30 hrs. (20% first pass)	NA

Simple/Medium: 6.6 hrs. labor / Complex: 21 hrs. labor

Model Complexity:
Simple 1-10 features
Medium 11-30 features
Complex >30 features

Lockheed program impact
Per 1000 Parts



Current process (without CSI):
Time to document change + time to quote change + time to incorporate change + time to resolve issues

Simple/Medium Complexity Part: .25 hrs + 2.1 hrs + 8 hrs + .8 hrs = **11.15 hours**
Complex Part: .25 hrs + 20 hrs + 20 hrs + 8 hrs = **48.25 hours**

Proposed process (with CSI):
Time to document change + time to quote change + time to incorporate change + time to resolve issues

Simple/Medium Complexity Part: .02 hrs + 1.7 hrs + 6 hrs + .6 hrs = **8.32 hours**
Complex Part: .02 hrs + 15 hrs + 15 hrs + 6 hrs = **36.02 hours**

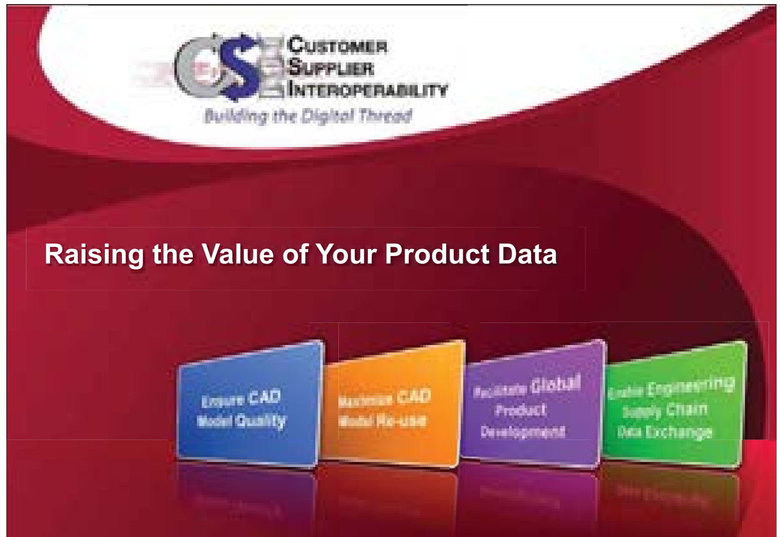
Savings per change:
Current process hours – Proposed process hours

Simple/Medium Complexity Part: 11.15 hrs - 8.32 hrs = **2.83 hours**
Complex Part: 48.25 hrs – 36.02 hrs = **12.23 hours**

Model Complexity:
Simple 1-10 features
Medium 11-30 features
Complex >30 features

Annual savings:

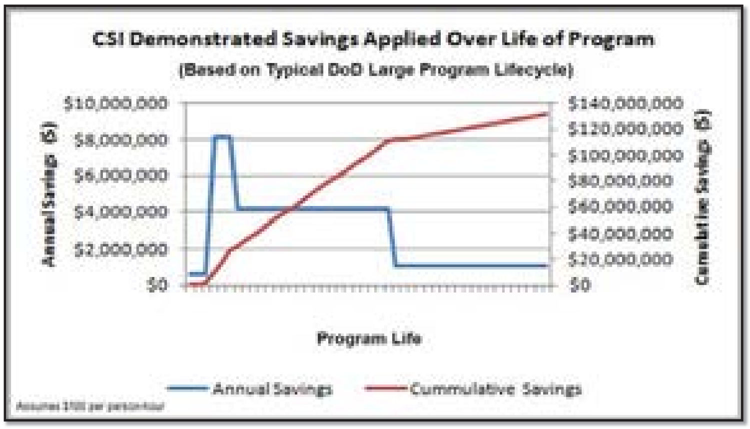
Open BTP PO's	Part Complexity	Hours saved per change	Percentage of parts by complexity	Labor hours saved per year based on expected change rate			
				25%	50%	75%	100%
1,000	Simple/Medium	2.83	95%	672	1,344	2,016	2,689
	Complex	12.23	5%	153	306	459	612
Total hours saved based on expected change rate				825	1,650	2,475	3,300
Estimated annual savings based on expected change rate and $100/hr labor rate				$82,500	$165,000	$247,500	$330,000



Raising the Value of Your Product Data

Product Data Integration & Interoperability Solutions

CSI Demonstrated Savings (ITI generated) (Original Scope)



Savings based on functions developed in Phase 1, integrated into CSI platform and deployed throughout supply chain on a large DoD acquisition

Savings Applied Across CSI Team Partners For A Typical Large Program

CSI End User Company	Active Mechanical CAD Models	Generate MBD (non-recurring)	Translate MBD (recurring)	3D ECO (recurring)	Producibility (recurring)	Total (non-recurring)	Total (recurring)
Lockheed	10,000	$8,200,000	$8,200,000	$3,300,000	$8,800,000	$8,200,000	$20,300,000
Honeywell	1,000	$820,000	$820,000	$330,000	$880,000	$820,000	$2,030,000
Rockwell Collins	20	$16,400	$16,400	$6,600	$17,600	$16,400	$40,600
	Total	$9,036,400	$9,036,400	$3,636,600	$9,697,600	$9,036,400	$22,370,600
				+Downstream impact	+Downstream impact	+Downstream impact	+Downstream impact

The Sustainable Enterprise: Enabling the Digital Thread

Model Based Enterprise Summit hosted at NIST
Gaithersberg, MD

Karen Kontos
December 13, 2012

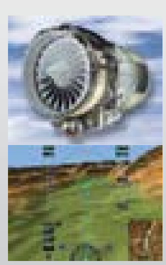
Honeywell

Honeywell Honeywell.com

Honeywell's Businesses

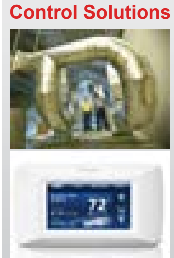
- $35-36 billion* in revenues, 50% outside of U.S.
- Nearly 130,000 employees operating in 100 countries
- Morristown, NJ global corporate headquarters

Aerospace



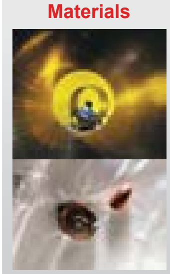
$10.8-11.2B*

Automation & Control Solutions



$14.7-15.1B*

Specialty Materials

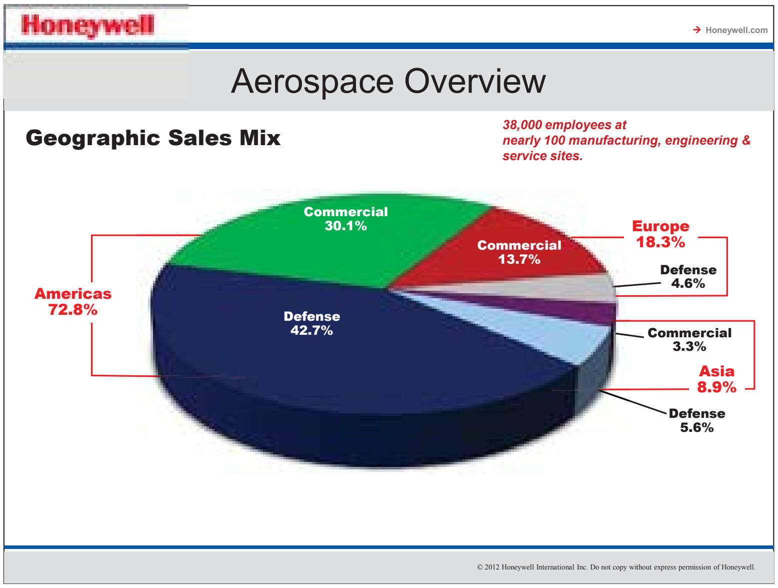


$4.3-4.5B*

Transportation Systems

$5.0-5.2B*

*2011 revenue estimate


Honeywell
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Aerospace Overview
Geographic Sales Mix
38,000 employees at nearly 100 manufacturing, engineering & service sites.
Commercial 30.1%
Commercial 13.7%
Europe 18.3%
Defense 4.6%
Americas 72.8%
Defense 42.7%
Commercial 3.3%
Asia 8.9%
Defense 5.6%
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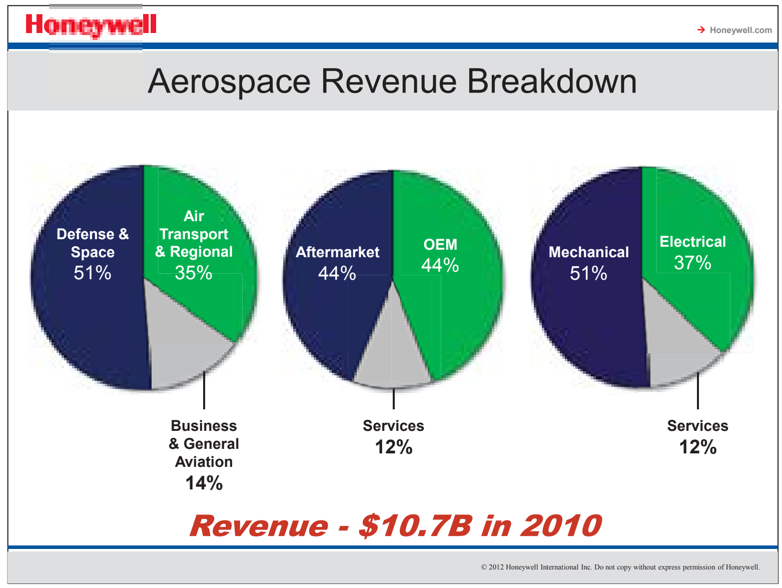
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Aerospace Revenue Breakdown
Defense & Space 51%
Air Transport & Regional 35%
Business & General Aviation 14%
Aftermarket 44%
OEM 44%
Services 12%
Mechanical 51%
Electrical 37%
Services 12%
Revenue - $10.7B in 2010
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Fighter/Attack/ Trainer Aircraft 30+ platforms
Human Space 10+ Platforms
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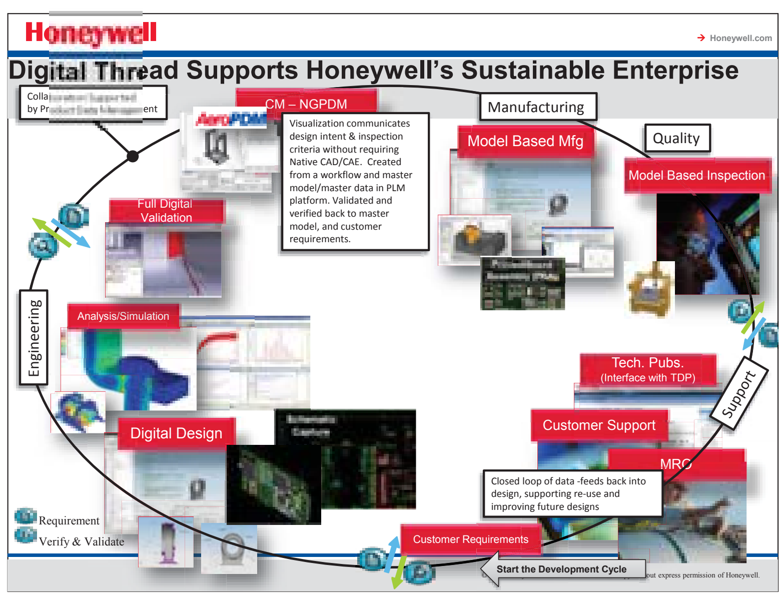

Honeywell
Honeywell.com
Digital Thread Supports Honeywell's Sustainable Enterprise
CM – NGPDM
Manufacturing
Quality
Model Based Mfg
Model Based Inspection
Visualization communicates design intent & inspection criteria without requiring Native CAD/CAE. Created from a workflow and master model/master data in PLM platform. Validated and verified back to master model, and customer requirements.
Full Digital Validation
Analysis/Simulation
Engineering
Digital Design
Tech. Pubs. (Interface with TDP)
Customer Support
Support
MRO
Closed loop of data -feeds back into design, supporting re-use and improving future designs
Requirement
Verify & Validate
Customer Requirements
Start the Development Cycle

The Honeywell Business Case for MBE and TDP

- Complexity of Products and Communication of Design Intent
  - Design Collaboration across hundreds of design communities (internal and external)
  - Support Honeywell as the design integrator of complex mechanical & electrical assemblies
  - Support of ISC (eliminate the re-creation of design intent downstream)
- Complexity of Aerospace Supply Chain
  - Complexity of Products
  - Product Lifecycle Support – long lifecycle, services is large portion of Honeywell business
  - Demands for Re-Use
  - Outsourced manufacturing for more than 50% of our products

Communication and exchange processes associated with digital data must become more efficient and robust to support a sustainable business

MBE/Digital Data as a Honeywell Strategy

- **Quality parts, on time, at the best possible price** – successful implementation of MBE can be a game changer for Honeywell
  - Quality
    - "Model is the master" is fundamental enabler that ensures quality parts that meet design intent, streamlined inspection processes
  - Development Cycle Time
    - Reduced opportunities for errors in design and manufacturing through early identification of manufacturing issues, facilitate MOT development/eliminate redundant efforts to re-create design intent
  - Reduced Costs
    - Reduced development cycle times and improved quality, also supports early analysis of manufacturing cost during design phase (DTC), and design for Manufacturability (DFM)

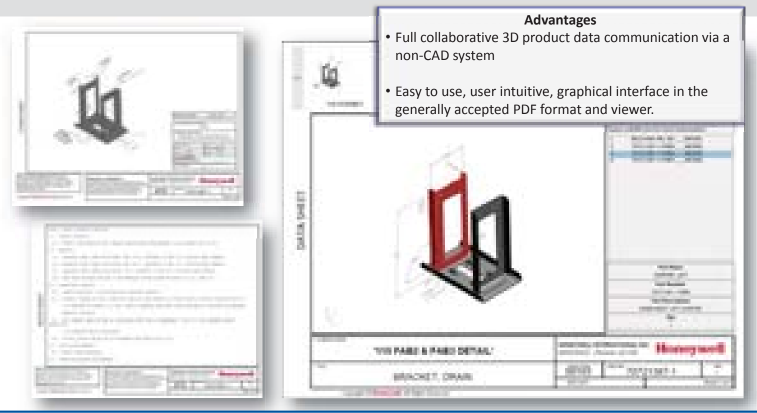
MBE is a competitive advantage. In the longer term, it is a necessary means to sustain business and to meet customer requirements.

2012 Honeywell MBE Highlights

- MBE Organization formally established as a part of Product Lifecycle Management/Engineering Operations in Aerospace
- Honeywell internal MBE/TDP initiatives in VPD™
  - Customer/Supplier Interoperability (CSI) project completed
  - TDP Strategy Defined, tools procured, process innovation and tool deployment in work
  - Model Based Engineering & Manufacturing Pilot Projects completed, supporting tool & process development, leadership support
- Honeywell External/Industry Initiatives and Standards Support
  - Participation/support of many initiatives in PDES, LOTAR, AIA, and others
  - Technical Data Package /alignment with MIL STD 31000

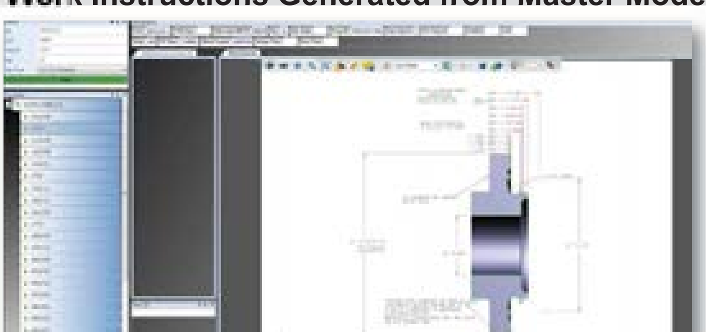
Support of key Aerospace standards is critical to achieving the sustainable enterprise. Opportunities for external funding help drive strategy development, timely execution, and critical vendor/tool alignment to meet customer requirements.

Automated PLM Collaboration Template



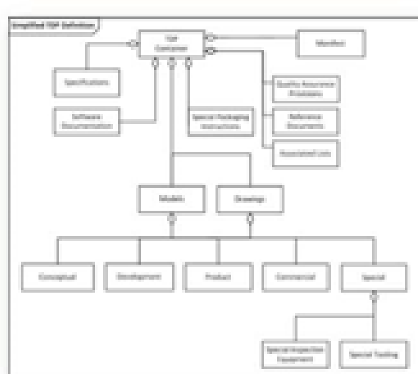
Revision history, EBOM, Notes, etc. embedded via automated workflows

Internal Use Case for Manufacturing – Work Instructions Generated from Master Model



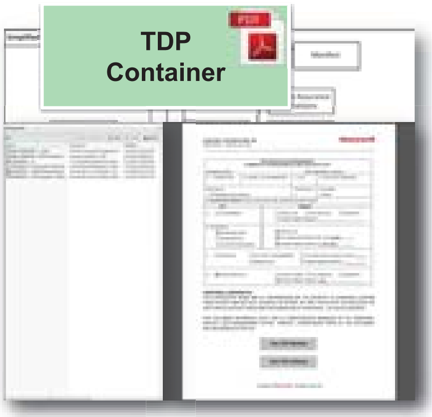
- Web-based , directly accesses PLM system where Bill of Process and Master Models live
- Shop and operators access system via web browser and have access to all required manufacturing documents

TDP Definition (Simplified)



- Contains all artifacts described by MIL-STD-31000A
- Intended for bi-directional collaborative communication
- Generated with automated workflows

The TDP Container



- PDF Container - generally accepted as a business document type, viewer is highly available
- PDF has established security processes
- PDF enables bi-directional communication between customers and suppliers

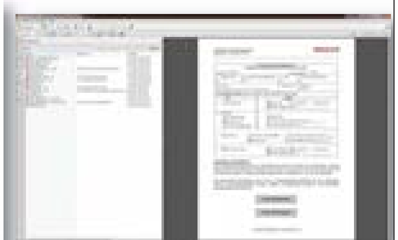
The Manifest

- Includes list of artifacts, specifications, BOM information, notes, key characteristics and requirements
- AP239 / PLCS for Machine to Machine / PLM to PLM communication
- MS Excel file supports human consumption and downstream extraction of data
  - Users know how to easily convert Excel files to other formats (i.e. XML, CSV, TXT, etc.)

TDP Use Cases: Phase 1 Implementation

- MCAD Piece Parts
- Internal / External Suppliers
- Specifications
- 3D Representations of ECAD
- BOx – Bills of Materials, Notes, Characteristics, Specifications, etc.
- LOTAR Archival
- MIL-STD-31000A Delivery

Enabling the Digital Thread: Examples of how MBE and the TDP Will Support Honeywell's Sustainable Enterprise



ECAD 3D PDF Example **MCAD TDP Example**

MBE/Technical Data Package Deployment Level and Timing

Honeywell Aiming for Level 5 Deployment in 2013

PTC PRODUCT & SERVICE ADVANTAGE

Creo View

Madhavi Ramesh
Product Management Director

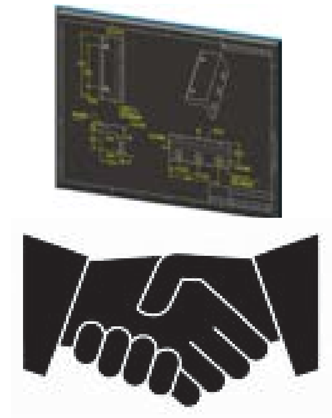
12 Dec 2012

Model Based Enterprise

PTC

2D Drawings – primary deliverables…

PTC

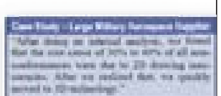


Problem Statement

PTC

Drawings are Human Readable, Provides All Information… BUT…

- Disconnected Data Sources
  - Information about the design in separate sources (Drawings, models, calculations, requirements, etc… – all with multiple versions)
- Recreating data in 2D and 3D (duplicated efforts)
  - Drawings are time consuming to create and duplicated effort
- 2D drawing are more prone to interpretation errors than 3D models
  - Drawings alone are not adequate to capture design innovations that engineers create
  - 30% - 40% of non-conformances are due to 2D drawings inaccuracies
- Drawings are not well suited for wide-spread collaboration across geographical barriers
  - Using the 3D data, provides audiences with access to whatever information they may need



Aberdeen report

Design– changes in real time

PTC

Design data – Processes, workflows, standards in place to manage ….

PTC

Users of design data– Upstream or downstream…

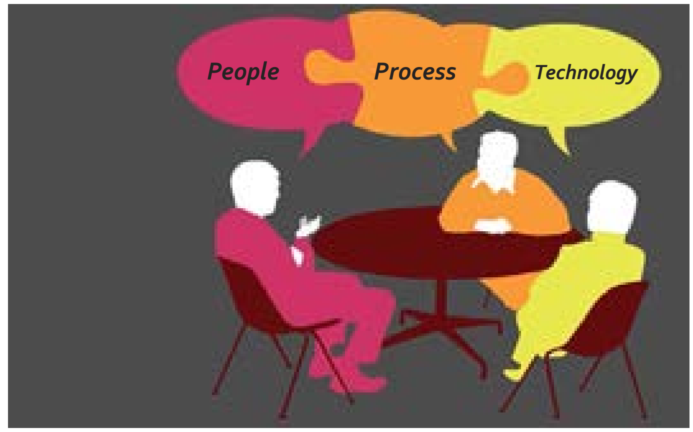
PTC

Collaboration– Review, feedback leads to product innovation

PTC

Key enablers of MBE

PTC



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Building Model Based Enterprises

Model Based Enterprise

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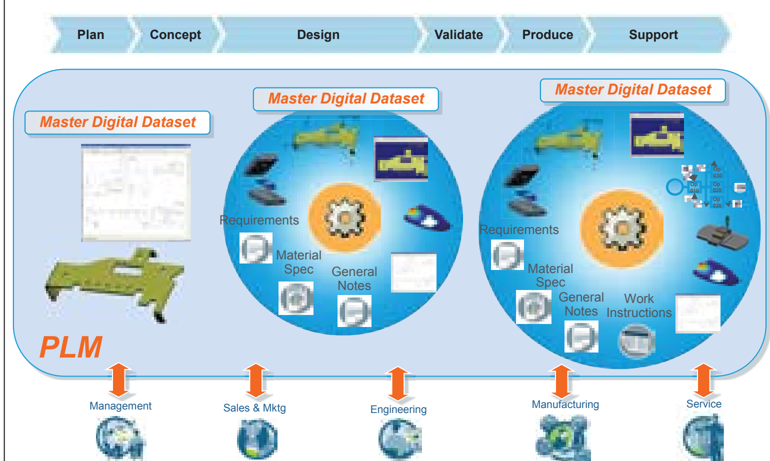
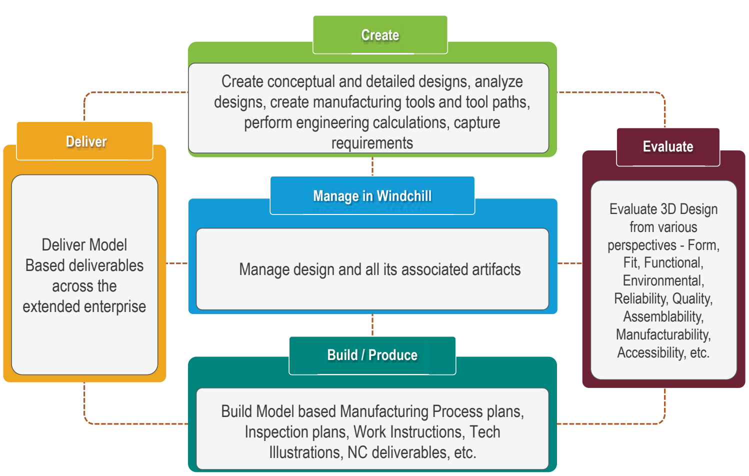


Model Based Enteprise solution from PTC

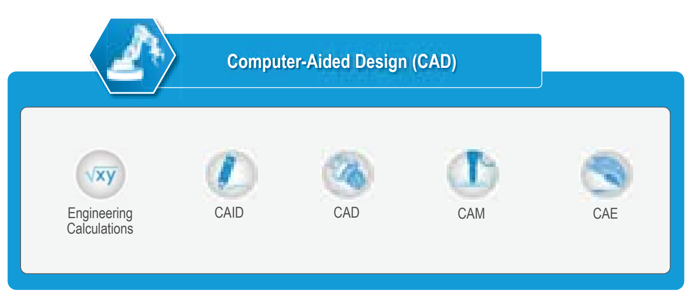
PTC



PTC Computer-Aided Design Capabilities

PTC

Create conceptual and detailed designs, analyze designs, create manufacturing tools and tool paths, perform engineering calculations



PTC Application Lifecycle Management Capabilities

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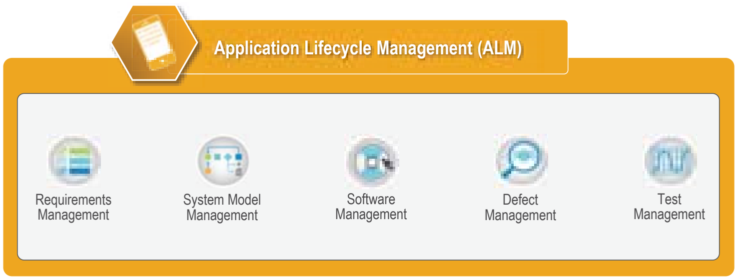
Manage product requirements, system models, software configurations, test plans and defects



PTC Supply Chain Management Capabilities

PTC

Manage components and suppliers, measure and manage compliance, analyze product cost

PTC Service Lifecycle Management Capabilities

PTC

Plan, manage, deliver and analyze service information, parts and warranty throughout the service lifecycle

PTC Product Lifecycle Management Capabilities

PTC

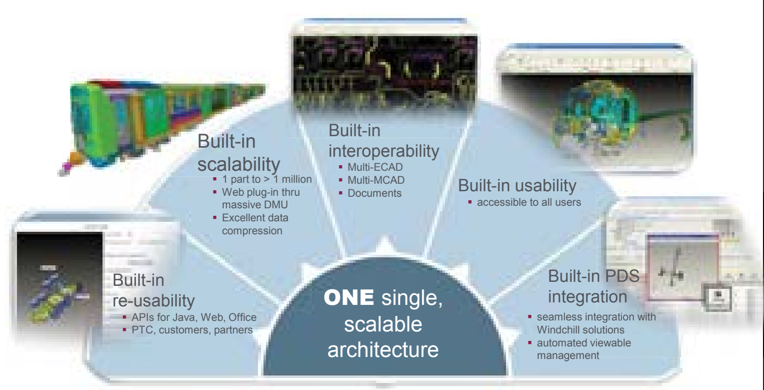
Evolve the complete definition of a product over its entire life

PTC Product Lifecycle Management Capabilities

PTC

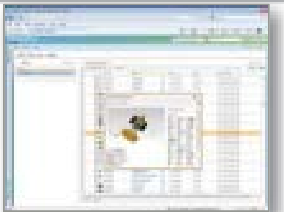
PTC's Visualization software – **Creo View**

PTC



Access “Viewable” truth

PTC


Single source of Viewable truth

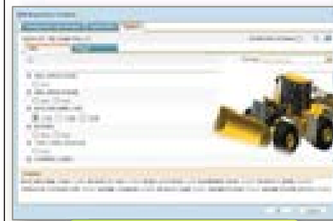

Integrated cross discpline BOM


3D Models, Metadata and Structure

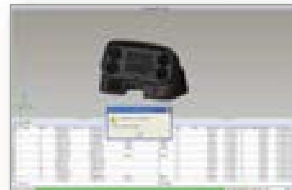

Load, Visualize, Navigate Massive assemblies

Visualize, Analyze variants

PTC

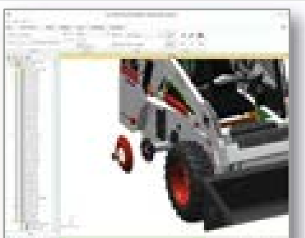

Visualize overloaded structure


Perform What-If studies on the Variants

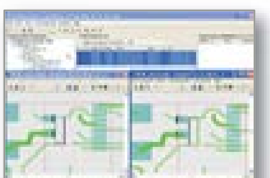

Analyse variants

Interrogate Design

PTC


Exploded View


Quarter cut

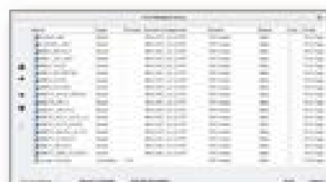

Review ECAD Design changes

Visualize, Validate PMI

PTC


Access, View PMI, Combination States

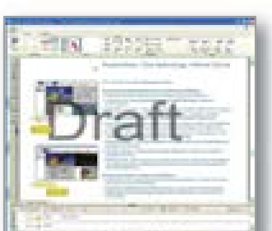

Ensure all critical dimensions are present


Print 3D Drawings

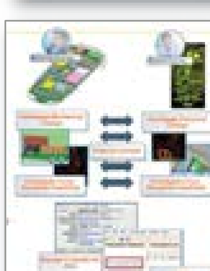
Collaborate on Designs

PTC


Color coding based on “Lifecyclestate”

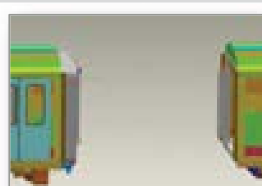


PDF Collaboration

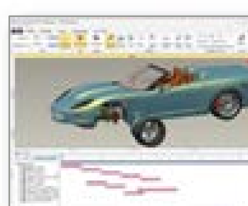

ECAD-MCAD Collaboration

Analyze designs

PTC

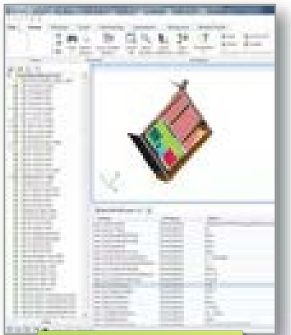

Mate and Align


Interference Analysis


Animation

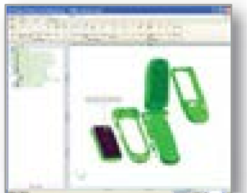
Visualize, Analyze Product Analytics

PTC



Analyze cost information

Visualize parts with their carbon footprint



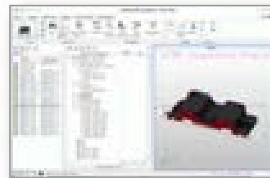
Identify parts based on regulations that are out of compliance

Generate work instructions

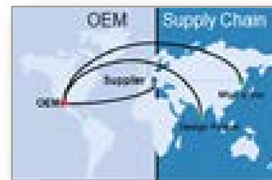
PTC

Associative EBOM-MBOM

Manufacturing Work Instructions



Access, Identify characteristics (Key, critical)

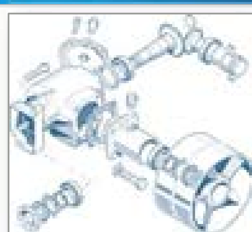


Share product data with suppliers

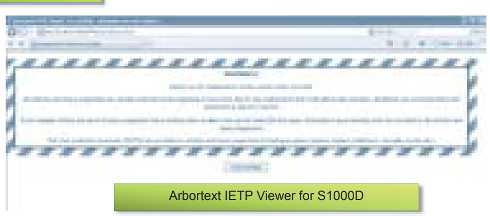
Generate 2D, 3D Tech Publications

PTC

Dynamically generate parts lists with callouts



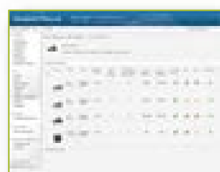
Create 2D illustrations



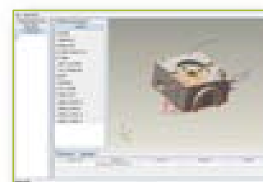
Arbortext IETP Viewer for S1000D

Other features

PTC



Visualization in Program and Portfolio dashboards

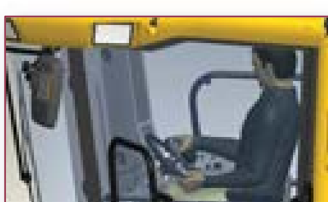


Access of MBD Information through custom applications

MBD data access

PTC

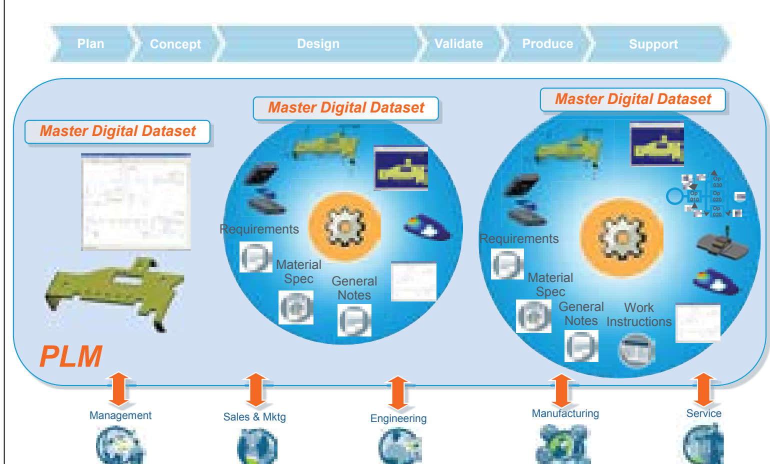
Mobile access to Model based design data



Immersive and Interactive evaluation of Digital Mockup

Creo View in a Model Based Enterprise

PTC



Open Manufacturing

Mr. Michael "Mick" Maher

Briefing prepared for: NIST MBE/TDP Summit

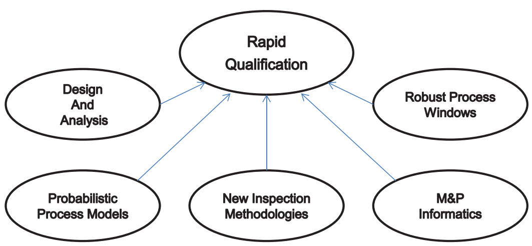
December 12, 2012

DoD Drivers for OM Going Forward

1. Need to Maintain Legacy Systems longer
   - Results in high mix, small quantities
   - In this environment often times the production processes originally approved for production are not appropriate for rapid response, small quantities
2. Need to maintain a robust industrial base that is not dependent upon DoD but can be responsive when called upon
   - Defense Spending shrinking as % of GDP, Currently 4.7%
   - Defense supplier base is concerned
3. Need more agile and rapid manufacturing capabilities
   - Fewer new systems with shrinking defense budgets
   - Need higher performance at reduced cost and weight
   - More prototype systems to keep performance innovation alive
4. Need to establish confidence in these new processes
   - If risks are not known and controlled, non-traditional/innovative processes will not be implemented

Open Manufacturing Vision

Enable Adoption of Additive Process and Bonded Structure for Defense Applications Using:

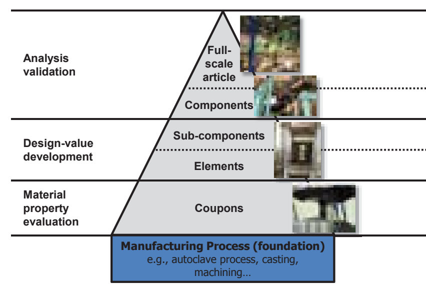


Accelerate the Manufacturing Innovation Timeline
Ensure Technology Acceptance and Adaptation

New Manufacturing Technologies must undergo extensive qualification and certification testing

Typical Aircraft Qualification/Certification Path

- Range is determined by extent of new material, process and technology being introduced; and the amount of iterations
- Rotor and UAV platform costs are lower, large transport costs can be higher



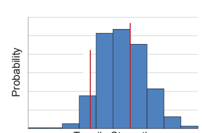
	Specimen Count	Cost ($M)	Time (Yrs)
Full-scale article	2-3	100-125	4
Components	10-30	10-20	3
Sub-components	25-50	10-35	3
Elements	2000-5000	10-35	3
Coupons	5000-100,000	8-15	2

Risk of unplanned cost and schedule impacts causes barrier to manufacturing innovation

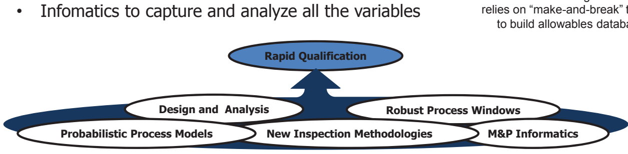
Open Manufacturing builds confidence for insertion of new manufacturing technology

- Establish a thorough process understanding
  - Understand all potential process variables
  - Quantify effect of these variables on the end product
- Modernize the toolsets the DoD manufacturing community implements to improve their products
  - The analysis community has successfully used modeling for years
  - Current aircraft are certified by analysis supported by testing
- Enabled by development and use of:
  - Process modeling to understand the bounds
  - Infomatics to capture and analyze all the variables

Finite element analysis provides high confidence predictions of structure properties for a given static load

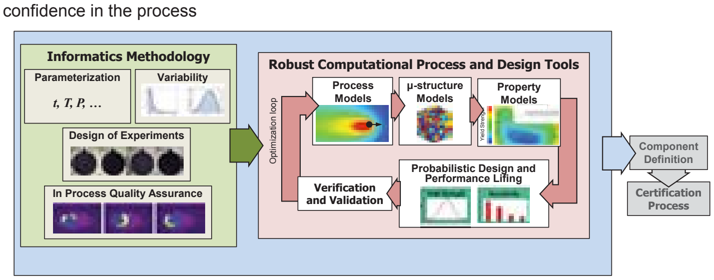


The manufacturing community relies on "make-and-break" testing to build allowables database



Open Manufacturing fundamentally changes how manufacturing variability is captured and controlled

Create a manufacturing framework that captures factory-floor variability and integrates robust computational tools, informatics systems, and rapid qualification approaches to build confidence in the process



OM probabilistic design is a new paradigm for rapid qualification of manufacturing processes

- Variability from the factory floor
- Propagate uncertainty throughout
- Rigorous verification and validation
- Probabilistically predict process and part performance
- Identify bounds of process window
- Optimize and control processes
- Build confidence and reduce testing
- **Reduced risk for new technology insertion**

OM Demonstration Technologies

Demonstration technologies chosen to focus and validate value of program

- Bonded Composite Structure: Holy grail for Composite community for last 30 years.
- Additive manufacture: Emerging technology that is stuck at the demonstration phase.

Bonded Composite Structures

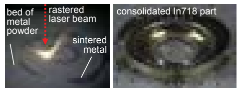
- Bonded Composite Structural Assemblies

bonded Pi-joint

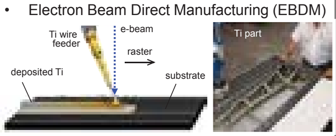
Process Variability
- Environmental
- Surface prep
- Cure
- Metrology
- Personnel

Metals Additive Manufacturing

- Direct Metal Laser Sintering (DMLS)



- Electron Beam Direct Manufacturing (EBDM)



Process variability
- 10^n welds

Accelerate the manufacturing innovation timeline for these high impact processing technologies

Establish Manufacturing Demonstration Facilities (MDF) to capture technologies and disseminate knowledge

- Service affiliated repository of focused manufacturing knowledge and infrastructure
- Independently demonstrate designs, manufacturing processes and manufactured products
- Curate and independently assess and validate data and models
- Build confidence for transition
- Enable small and medium enterprise

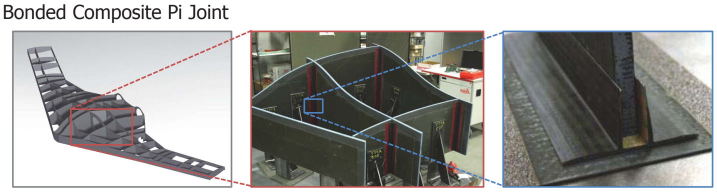
Current OM MDF's

	Penn State University, Applied Research Lab (PSU-ARL)	Army Research Laboratory, Aberdeen Proving Ground	Air Force Research Lab, Kirtland Air Force Base
Service Affiliation	U.S. Navy	U.S. Army	U.S. Air Force
Technology Focus	Additive Manufacturing	Bonded Composites	High Value/Low Volume Assembly
Functional Focus	Process Models and Qualification Schema	Materials and Process Database	Smart Manufacturing Framework

Trusted agent and transition point for manufacturing technologies

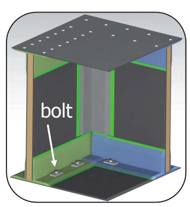
Bonded Composite Exemplar

Bonded Composite Pi Joint



- Numerous sources of bond strength variability
- The manufacturing process is not equipped to capture all of the variability
- Therefore the certifiers and designers don't have confidence that the process is well-controlled.
  - DoD Joint Service Specification Guide (SSG-2006) for Aircraft Structures, Part 3.10.5.d.:

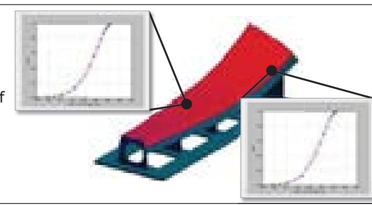
    "Bonded structure shall be capable of sustaining residual strength limit loads without a safety of flight failure with a complete bond line failure or disbond."
  - **Bolts are added after bonding**



Lower risk by capturing the manufacturing process

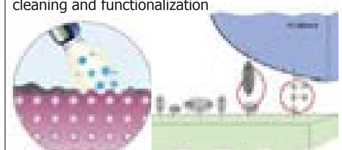
Material and process informatics capture parameterized process conditions and variability

Modeling quantitatively predicts the impact of factory-floor process parameters on bond strength, defect generation, and defect distribution across structures in real time



Reduced Process Variability

Automated atmospheric plasma for surface cleaning and functionalization



Metrology

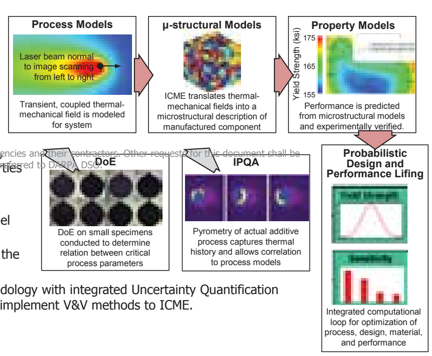
Laser bond inspection to quantify as-manufactured state of a bond line

Improved process and quantitative prediction of as-manufactured state enable bonding without bolts

Additive Manufacturing Exemplar

Direct Metal Laser Sintering of Inconel 718+ (Ni-Cr superalloy)
Take the process from laboratory to industry

Rastered laser beam sinters/consolidates metal powder to create structural parts



- Physics-based models of the transient process, microstructural evolution, and resultant properties
- Identify sources of variation using Design of Experiments (DoE)
- Incorporate variation input at all levels of model hierarchy.
- Incorporate In Process Quality Assurance into the manufacturing system for empirical feedback.
- Utilize Verification and Validation (V&V) methodology with integrated Uncertainty Quantification (UQ) – key to robust modeling. OM is first to implement V&V methods to ICME.
- Implement Tool Maturity Level (TML)
- Demonstrate on engine harness component.
- MDF becomes repository for knowledge.

Extend ICME concepts into integrated probabilistic design and lifing methodology to serve as a new paradigm for rapid qualification.

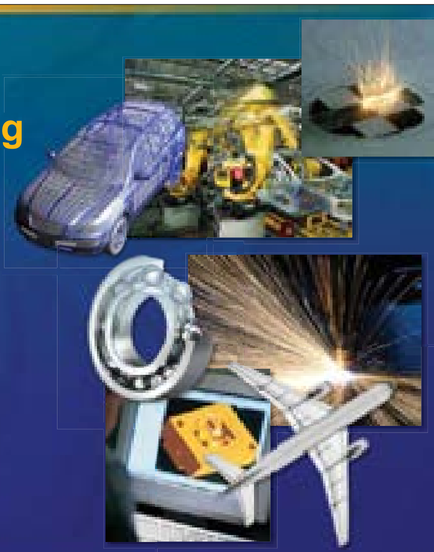
Open Manufacturing Impact

Establish open manufacturing tools that accelerate and encourage innovation through new manufacturing technology appropriate for the next 5 to 20 years by enabling rapid and affordable prototyping of new design concepts, and establish (process and materials models) for mitigating and addressing risks associated with these new approaches.

Smart Manufacturing at NIST

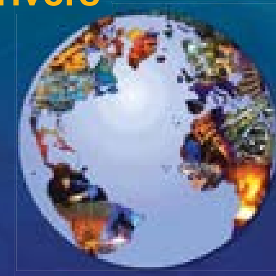
MBE Summit
December 2012

Simon Frechette
National Institute of Standards and Technology
U.S. Department of Commerce



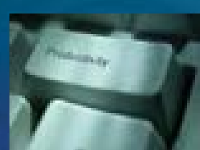
Key Manufacturing Drivers

- Increased rates of
  - Global competition
  - International trade
  - Technological change
- Increased demand for:
  - Energy efficient and sustainable manufacturing
  - Better quality and innovative products
  - Higher productivity and lower cost



Key Challenges

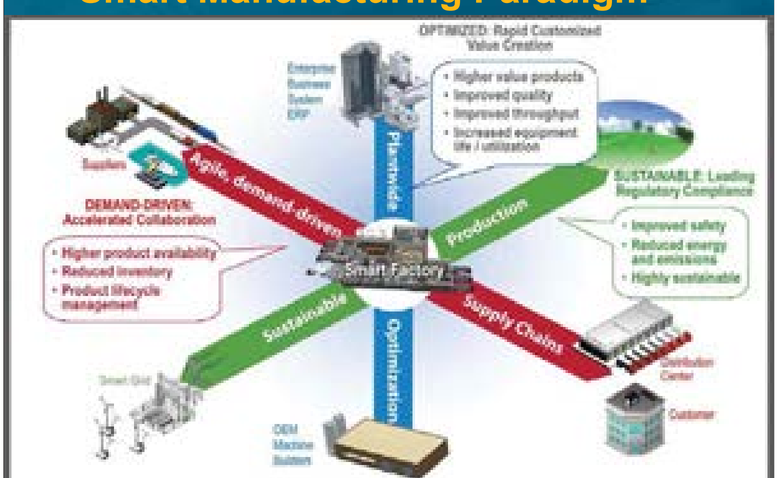
- Better methods and tools for diagnostic and prognostic
- Balance life-cycle performance and minimum first-cost
- Improved R&D support for new standards, codes, and regulations
- Better ways to link pre-competitive R&D gaps with scale up



What is Smart Manufacturing ?

- Use high-fidelity models and intelligent software
- Enable innovative production and products
- Enhance economic/sustainability performance

Smart Manufacturing Paradigm



What is EL's scope of SM activities?

- Production systems at the equipment, factory, and network levels
- Smart operating systems to monitor, control, and optimize performance
- Systems engineering-based architectures and standards
- Sensing, computing, communications, actuation, and control technologies

What is EL's role in SM?

- Measurement science
- Technical standards
- R&D testbeds

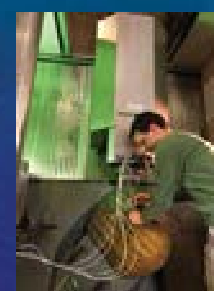
Traceable Needs and Roadmaps

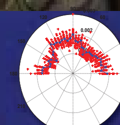
Programs Supporting Smart Manufacturing

- Smart Manufacturing Processes and Equipment
- Next-Generation Robotics and Automation
- Smart Manufacturing Control Systems
- Systems Integration for Manufacturing and Construction Applications
- Sustainable Manufacturing
- Manufacturing with Sustainable Materials

Smart Manufacturing Processes and Equipment Program - Objective

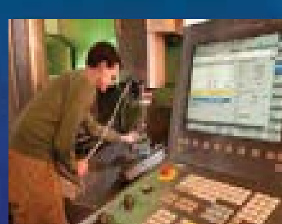
Rapid, cost-effective production of innovative, complex products using advanced manufacturing processes and equipment





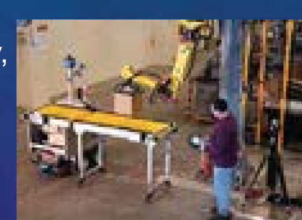
Smart Manufacturing Processes and Equipment Program

- Geometric accuracy of axes of rotation (ISO 230-7:2007)
- Geometric accuracy of turning centers (ISO 13041-2:2008 and ISO 13041-3:2009)
- Machine tool vibrations (ISO/TR 230-8:2010)
- Machine tool measuring capability (for on-machine measurements of parts) (ISO 230-10:2011)



Next Generation Robotics and Automation Program - Objective

Safely increase the versatility, autonomy, and rapid re-tasking of intelligent robots and automation technologies

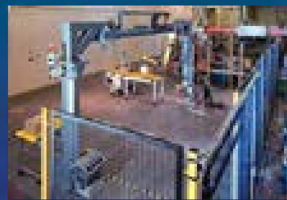


Next Generation Robotics and Automation Program

- **Industrial Robotics Safety Standards** –Critical technical contributions to OSHA-referenced Robotics Industries Association (RIA) and ISO robot safety standards. Standards support new robot capabilities that increase productivity and allow some forms of human-robot collaboration

.

- **Automated Guided Vehicle (AGV) Safety Standards** – Testing results on non-contact sensors improved AGV safety standard developed by ANSI/ITSDF B56.5.

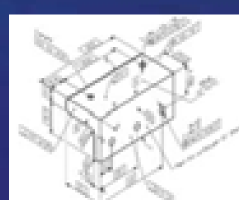


Smart Manufacturing Control Systems Program - Objective

Enable real-time monitoring, control, and performance optimization of smart manufacturing systems at the factory level

Systems Integration for Manufacturing and Construction Applications Program - Objective

Integration of engineering information systems used in complex manufacturing networks to improve product and process performance



Systems Integration for Manufacturing and Constructions Applications Program

- **Data exchange**
  - Over 68% of SMEs use STEP
  - U.S. aircraft manufacturers deliver digital-only aircraft design to FAA
  - Conformance tests for PMI
- **Systems Engineering**
  - Systems engineering standards
  - Engineering requirements

Sustainable Manufacturing Program

Objective: To develop and deploy advances in measurement science to achieve sustainability across manufacturing processes enabling **resource efficiency and production network resiliency**

- **Sustainable Processes and Resources** – enabling standards for characterizing and assessing sustainability performance (energy, materials, resiliency)

Manufacturing with Sustainable Materials Program

Objective: To develop and deploy measurement science, measurement standards and evaluated data needed to advance the **identification, optimization and application of more sustainable materials** for use in manufactured products

- **Identifying Alternative Sustainable Materials** – providing measurement science for identifying sustainable alternatives
- **Processing and Fabrication with Sustainable Materials** – providing measurement standards and protocols for assessing the quality of alternatives
- **Reliability of Sustainable Materials Replacements** – providing means to test the long-term reliability of sustainable materials replacements

Partnering Strategies with Industry

- Planning and Roadmapping Workshops
- Testbeds, Facilities, and Tools
- Standards Engagement
- Cooperation Mechanisms
- Other Tech Transfer Mechanisms
- NIST Sponsored Events

Summary

- We are getting smarter
  - Technical Data Package and supply chain
  - MBE for design including PMI
  - Model validation
  - Model based inspection (M7)
  - Data exchange (AP242, 3DPDF, JT, etc)
- We are not as smart as we could be
  - Systems engineering
  - Product lifecycle (both directions)
  - Predicting cost, controlling schedules
  - Modeling new materials and manufacturing processes (composites, additive,

The Army's Implementation of a Net-Centric Model Based Enterprise

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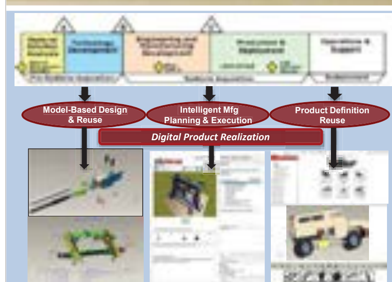
Net-Centric MBE to support the integrated weapon system lifecycle



Schedule & Cost

MILESTONES	FY11	FY12	FY13	FY14
Configure and Deploy Product Data Management System				TRL 6
Develop 3D Product Data Packages for select systems			TRL 7	
Re-use 3D Product Definitions at Depots. Acheive Tech-Transition				TRL 7
Develop Business Case for MBE implementation				

Purpose: This program seeks to develop, deploy and integrate Model Based Enterprise technologies and processes within the Army's organic base to reduce acquisition costs, risks and lead times

Major Capabilities:

1) Enterprise adoption of mature product data tools to include: Fully-annotated models, 3DPDFs, Digital Work Instructions for manufacturing operations, 3D model validation, 3D based technical publications and 3D based engineering analysis tools.
2) Development and deployment of technical and business processes to support the MBE tools described above.
3) Development and implementation of a Product Data Management system to support the management of data elements throughout the acquisition lifecycle between engineering service agencies, Product Managers, Depots and the defense manufacturing base.
4) Development of standard's based MBE technologies that allow for the free dissemination and reuse of product data elements within the organic and industrial base.

Warfighter Operational Benefits:

- Reduced training time for field level installation
- Access to relevant product data to support operations
- Reductions in Mean Time to Repair (MTTR)
- Improvements in parts availability

Transition:

- JPO MRAP: TOW-GPK Installation Instructions, 3Q FY12
- PM-SW: CROWS -01 and -05 IETMs, 1Q FY13
- PM-SW: M2A1 Quick Change Barrel 3DTDP, 2Q FY13
- PM-CCS: Service Information Center for Rhino, 2Q FY14
- PM-GCV: Development of RFP language, 2Q FY13

MBE is an enabling capability that drives out acquisition costs

BLUF: Summary of Major Achievements

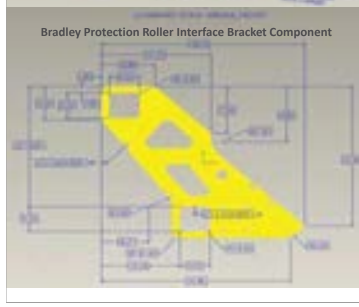
- Development and implementation of fully-annotated CAD models
  - Modeling SOP has been adopted by the ARDEC enterprise and has been shared with TARDEC as well.
  - Fully Annotated modeling has been done for the M2A1 and several Spark II Mine Roller Interface brackets (Bradley & Max-Pro)
- Establishment of a CAD validation capability
  - Validation ensures that CAD data can be used to drive manufacturing operations
  - Currently using the established processes to validate the M2A1 Quick Change Barrel 3DTDP
- Creating a 3DTDP for PM-SW's M2A1 Quick Change Barrel
  - A modern and consistent product definition reduces manufacturing risk and cost
  - The final 3DTDP, to include manufacturing process data, will be used in the upcoming procurement action
- Animated Digital Work Instructions for fielded systems
  - M153 Common Remote Weapon Station: Interactive Technical Repair Manual will be provided to Warfighters to reduce MTTR
  - TOW-GPK: Installation Manuals have been fielded to reduce War fighter assembly times
  - M2: Digital DMWR will reduce training times for new or cross-trained operators at ANAD
  - Max-Pro Dash Interface brackets: Documented assembly and weld processes reduced manufacturing risk for industry
- Deployed a pilot Enterprise Product Data Management (ePDM) environment
  - Created a Windchill 10.1 instance at ARDEC's PIF
  - Created areas for M24A1, Kiowa Helicopter and M2A1 products
  - Serving as a body of knowledge for AMC's ePDM initiative.

BLUF: Major Activities in Process

- Create and Deploy a Service Information System (SIS) to support logistics operations
  - The SIS will be an HTML portal where soldiers can access 3D, interactive logistics data
  - Reductions in assembly time, training and MTTR are feasible under this effort
  - TTA signed with PEO-AMMO
- MIL-STD-31000: A new product data standard
  - Will help the acquisition community obtain 3D data from OEMs
  - Provides the basis for standardizing and modernizing the Army's technical data
  - Helps to ensure that product data can be used to drive manufacturing during sustainment
- Implementation of MBE capabilities at ANAD
  - Generation of an MBOM for the M2A1 using MPM-Link
  - Updating and modernizing shop-floor procedures for the M2A1 conversion process
  - Training ANAD Tech Pubs personnel on Digital Work Instruction software
- Interactive Electronic Technical Manual for installing the SPARK II
  - Reduce operator training times
  - Reduce SPARK II installation times in theatre
- Evaluate and implement reverse engineering technologies
  - Enables the Army to develop 3DTDPs from physical hardware

TECHNICAL INFORMATION ON MBE CAPABILITIES

Fully-Annotated CAD Modeling



Proven Technology and Process:

- Mature Fully-Annotated Modeling Standard Operating Procedure
- Over 100 M2A1 models have been complete
- 2 major protection roller interface brackets are complete
  - Bradley Fighting Vehicle
  - Max-Pro Dash MRAP Vehicle.

3D Technical Data Packages

Interactive Inspection Documents

Manufacturing Process Data Files

Interactive Design Documents

Digital Work Instructions

"Prototypical" 3D TDP
Using the standard 3DPDF format

3D Technical Data Packages: Industry Assessment

Objectives:

1. **Connect** with individuals at supplier companies that are responsible for
   - receiving technical data and models
   - handling quotes/estimation
   - working with models related to design/production
2. **Drive target decision makers** to view online demonstration/example of the 3D TDP tool and video instructions to describe key features and usage of 3D TDP
3. **Gather Feedback** from the ARDEC supplier base

Summary of Results:

- **89%** of respondents feel that the **3D TDP is better or much better** than 2D drawings for conveying design intent.
- **84.4%** of respondents plan to use the 3D TDP in their **manufacturing planning**
- **76.1%** of respondents plan to use the 3D TDP to develop their **CAM program**
- **73.9%** of respondents plan to use the 3D TDP as an **instrument to convey intent for shop floor**

Assessment conducted jointly between NIST, ARDEC and industry partners

Creating the first 3DTDP: M2A1 Quick Change Barrel acquisition

Project Objective: Provide validated, 3D product data that can be used to procure QCB kits

Major Deliverables:

1) Fully-Annotated PRO-E models
2) Published nominal .STP files
3) Published design 3DPDFs
4) Validated CAD models and derivatives
5) MPDFs for hard to source components
6) Digital Work Instructions for assemblies

Value Proposition: A modern Product Data package with supplementary manufacturing process data will:

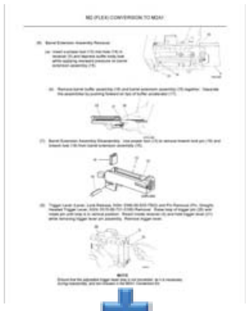
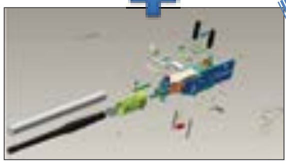
- Increase the number of bids from small manufacturers
- Reduce cost, risk and lead times for system acquisition

Digital Work Instructions: Installation & Repair Manuals

- Utilized manual and laser scanning techniques to reverse engineer model data
- IETM will be immediately fielded when complete: summer, 2012

- Single CD containing HTML based menu and multiple 3DPDF work instructions
- Instructions have been fielded with each system.

Digital Work Instructions: Supporting ANAD shop floor operations

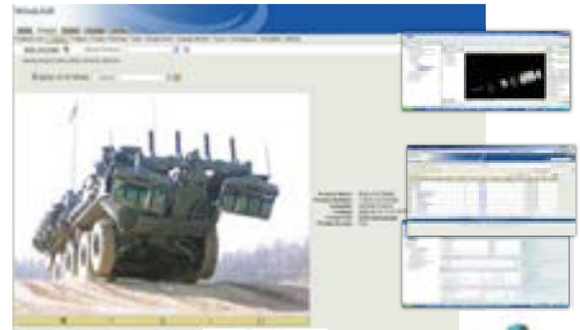




• Replace 2D paper instructions with a digital, interactive format that more effectively conveys each step

<u>Value Proposition</u>: Work instructions can be rapidly updated and redistributed based on process & product changes. Reduces lead times and costs associated with training new operators

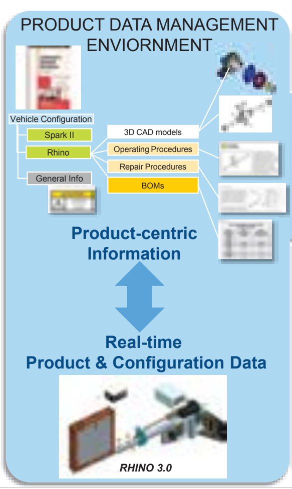
Data Management using Windchill: Supporting PM-CCS

Customer Requirements → Pro E Design Mfg Review Windchill FEA → Prototype → Qualification → Theater (first Q) / R&D Centers/ Depots/ Commercial Source

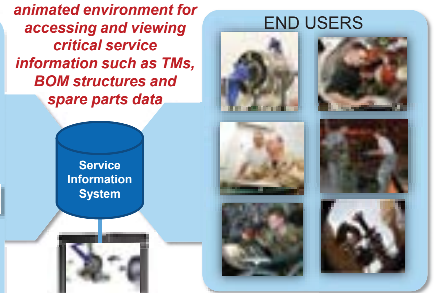



Manage different Spark II bracket configurations, provide producibility reviews and manage production operations for PM-CCS

What is a Service Information System



SIS provides a 3D animated environment for accessing and viewing critical service information such as TMs, BOM structures and spare parts data



- ✓ Service information is interactive, easy to understand and up-to-date
- ✓ Service information is specific to the role of the user, their task and the specific configuration of the product
- ✓ Service outcomes include a closed-loop to communicate to engineering
- ✓ IT investments connect product development, service planning and technical information

Implementing Digital Manufacturing Tools to connect and enable an organic manufacturing network

The Accelerated, Adaptive Army Fabrication Enterprise Vision

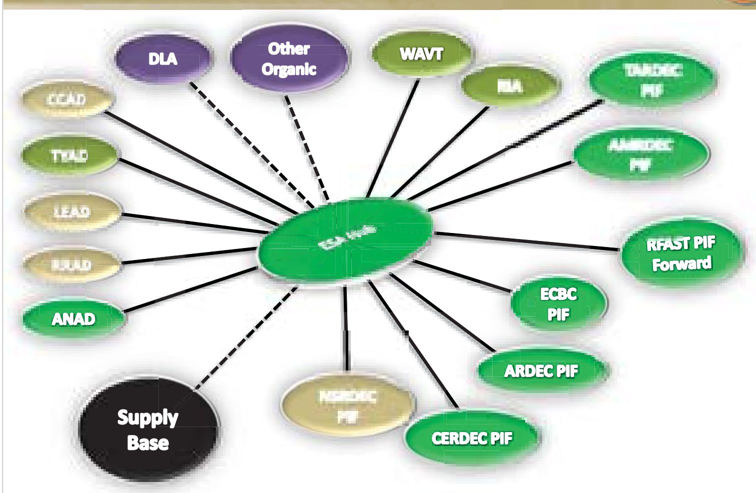
FY13/14	FY15	FY16
Deploy A3FABE Tools and Infrastructure throughout PIF/Army enterprise	Concurrent delivery of Prototype Platform Design (GCV, AVM, etc.) Concurrent delivery of Prototype Weapon System (ARAS, Crows, XMxxx. ATD)	

- Piloting and training on manufacturing tools
- Develop PIF MRL feedback loop
- Select prototype systems for prototype production
- Establish organic cloud-based manufacturing technology environment
- Deploy increments of Complex Assembly and Manufacturing Solutions
- Deploy MT Connect / Real Time Online architecture at multiple organic sites
- Utilize advanced physics-based manufacturing planning tools to transfer prototype production knowledge to organic base

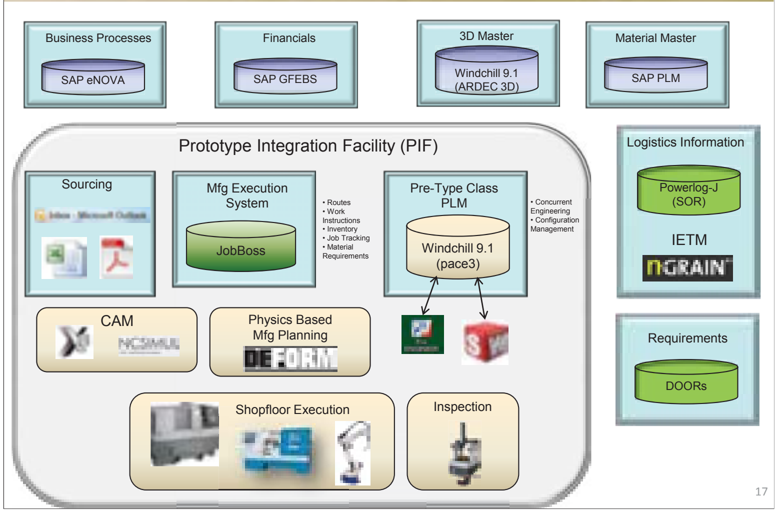
PIF Enterprise Manufacturing Engineering and Prototype Builds ← Manufacturing Readiness Feedback; ← Objective Cost Analysis; → LRIP (PIFe / Depot); → * Full Rate @ Depots

Output: Prototype weapon system with Army owned, design and manufacturing knowledge for next generation weapon system improvement and sustainment

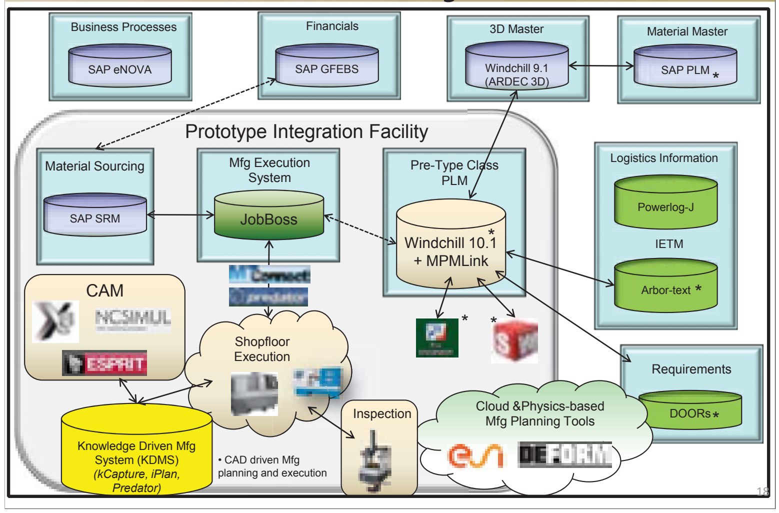
The Distributed Organic Manufacturing Network



The A3FABE Digital Infrastructure: Today's set of tools



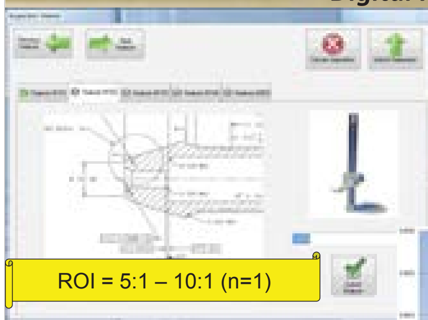
The A3FABE Digital Infrastructure: Tomorrow's Integrated Solution



A3FABE Accomplishments – FY12

Summary of Accomplishments	
1Q:	• Established RDECOM Working Groups • Piloting PIF-wide RFAST RFQ process using Windchill Enterprise tool for quotes and job "award" • Piloted organic-to-industry sourcing tool
2Q:	• Executed several PIF sourcing quotes event for RFAST parts using Windchill • Deployed MT-Connect enabled platform for prototype projectile inspection data
3Q:	• Initiated Kiowa PLM project to create virtual BOM structure for Nose Mounted Sensor Ground Support Equipment • Initiated PIF BCA MRAP spare parts project • Tested and validated additive manufacturing equipment with weapons system components
4Q:	• Developing SAP SRM tool in prototype production environment • Deployed machining optimization tools and piloted on several complex weapon parts • Supporting DARPA AVM program (iFAB/Fang). CRADA pending. • FY13 Product and Technology planning

A3FABE Accomplishments FY12: Digital Inspection



ROI = 5:1 – 10:1 (n=1)

Digital Real-Time Inspection:

- Reduces time for lot acceptance
- Reduces the risk of scrap
- Enables correlation between machining parameters, tool wear and part features
- Enables remote quality management

Process:

- Operator uses wired equipment to conduct in process inspection procedures
- Dashboard analyzes and displays data based upon engineer's specification
- Alarm is triggered when inspected dimensions are outside the operation's defined control limits

A3FABE Accomplishments FY12: Machining Optimization

Generate CNC Program

- Design machining fixtures
- Select tooling
- Import tooling, fixtures and part into standard CAM environments
- Publish G-Code

Optimize CNC Program

- Import CAM program or G-Code into optimization tool
- Optimize feeds and speeds based upon material type
- Eliminate air-cuts and redundant tool movements

THE PROCESS

Investments in NC optimizationn software have enabled ARDEC's PIF reduce cycle times for machined parts

Components optimized include:
- *Armored Cable Box*
- *Mortar Base Plates*

Results for Cable Box Optimization

Return on Investment: 69
Total Cost Savings: $5,250

Baseline: 1h 42m	($255/part)
Investment: 30m	($185)
Savings : 28m /part	($70/part)
Number of Parts: 75	

ROI: (2100m-30m)/30m = 69
TCS: ($70/part*75parts)=$5,250

Achievable ROI Range

ROI = 14:1-70:1 (n=3)

SIEMENS

What is in NX Cam

NIST 2012 Maryland.

By: Sada Reddy   Technical sales.

NX

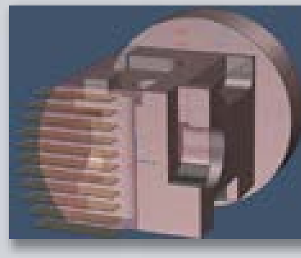
CAM Modules

- Milling
- Turning
- Wire EDM
- Feature Based Machining
- GMC (Generic Motion Controller)
- Postprocessors + Libraries + Shop Docs
- Simulation (IS&V) + DNC
- Open Architecture & Automation
- Geometry

2.5 Axis Milling.

Application: *- Machinery and Electronics Components.*

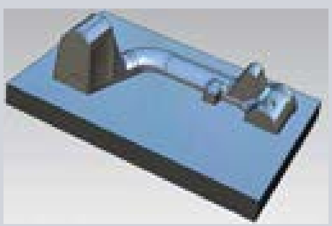
Geometry: *Points, Lines, Arcs, Splines, Sheet + Solid Bodies and Edges.*

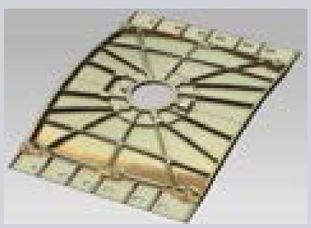


3-Axis Contour Machining.

Application: *Tool + Die, Aerospace, Medical and Consumer.*

Geometry: *Points, Lines, Arcs, Splines, Sheet+ Solid Bodies And Edges.*

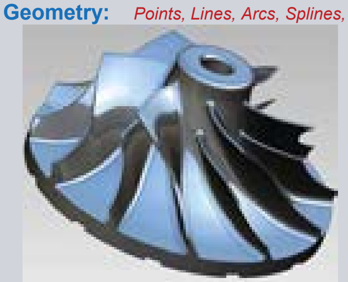


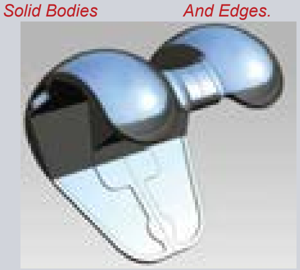


Multi-Axis Machining.

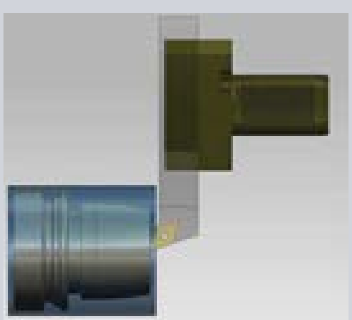
Application: *Aerospace and Medical.*

Geometry: *Points, Lines, Arcs, Splines, Sheet + Solid Bodies And Edges.*



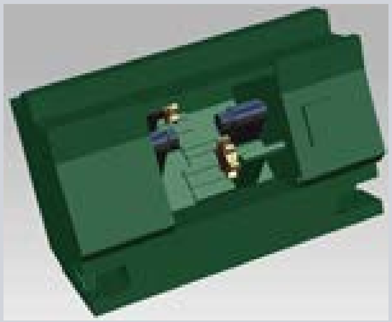


2-Axis Turning.

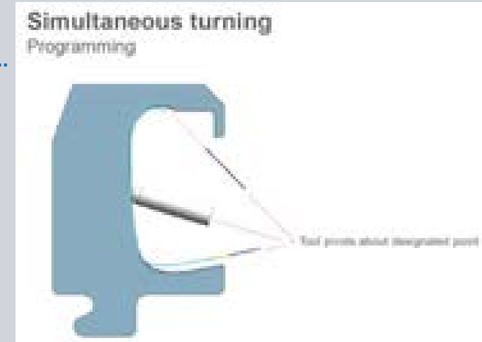


Mill-Turn Machining.

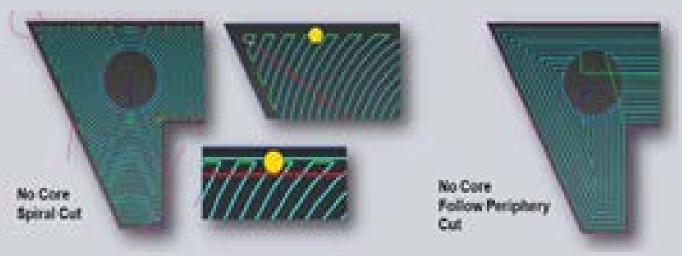
Sync. Mill-Turn



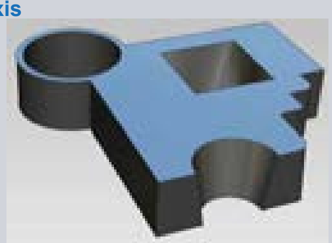
B-Axis Turning..



Interface

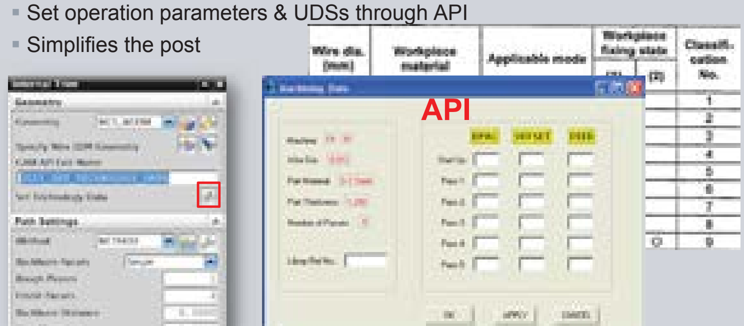


WEDM Multi-Axis



NX/Open exit to access technology data at the operation level

- Use API Exit to interface with machine specific technology tables
- Have data accessible at the operation level, stored with the operation
- Set operation parameters & UDSs through API
- Simplifies the post



NX/Open exit to access technology data at the operation level

SIEMENS

- Use API Exit to interface with machine specific technology tables
- Have data accessibl… with the operation
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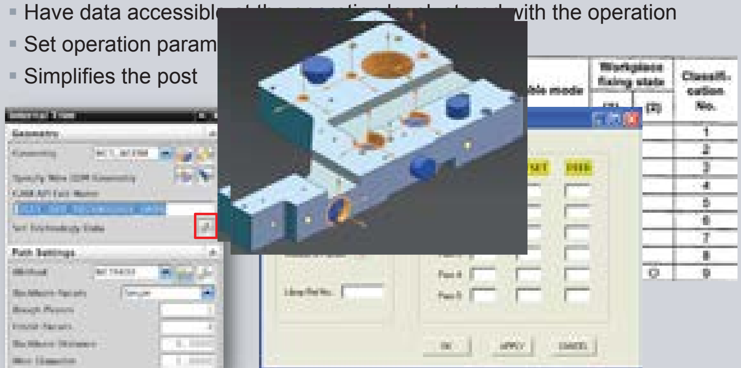
- Simplifies the post



Color and Attribute Features (1/2)

SIEMENS

- Feature recognition based on color & attributes
  - Define feature types with corresponding color/attribute criteria through MKE (Machining Knowledge Editor)
  - Add face attributes & PMI to features
  - Targeted at complex feature geometry
  - Requires model "markup" for manufacturing

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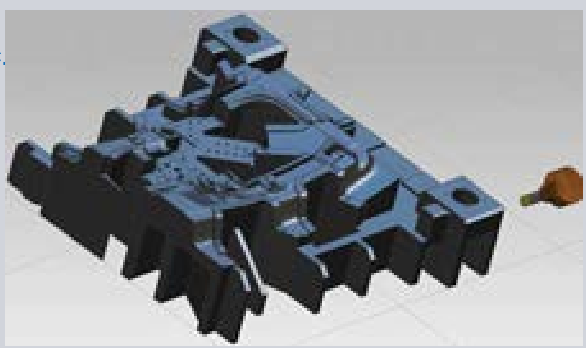
GMC.



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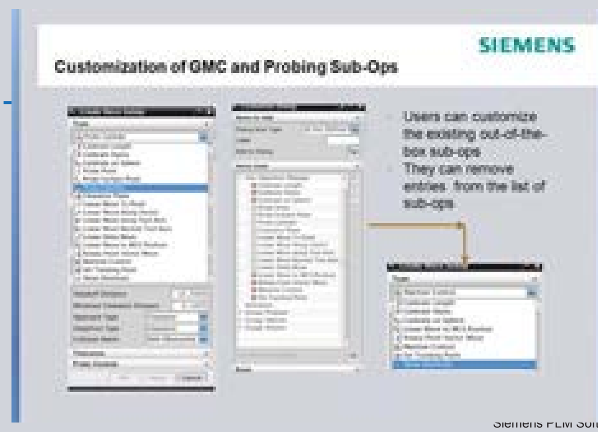
GMC –



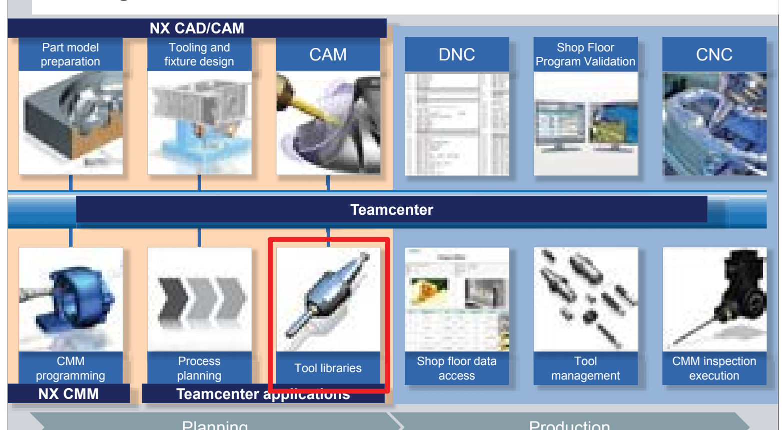
Shop Documentation.

SIEMENS

- Scope
  - All of Setup or Selected Program/Object
  - Mill/Drill/Turn/WEDM/Probe Operations
  - Replaces Post Versions
- Template Customization
  - Use Excel to edit
  - Easy to create and modify
  - Requires no knowledge of TCL or MOM
- Output
  - Page content length
  - Repeat title
  - Tool and Operation tables
  - Graphics
  - Part attributes
  - Over 1000 MOM variables

Tooling Libraries

SIEMENS



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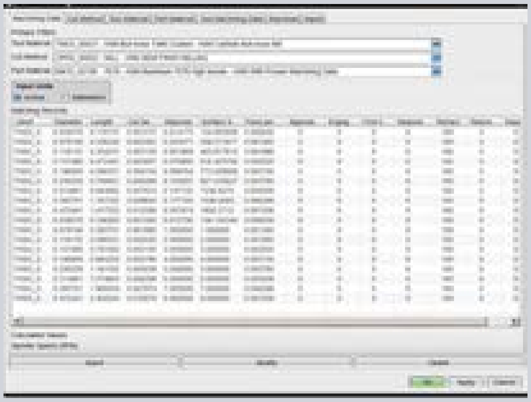
Tool/Material Database.



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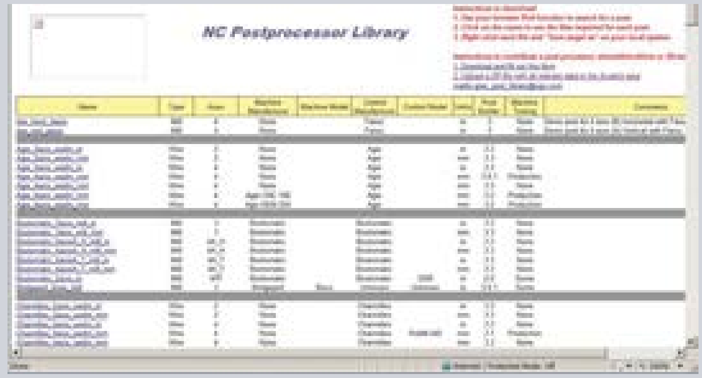

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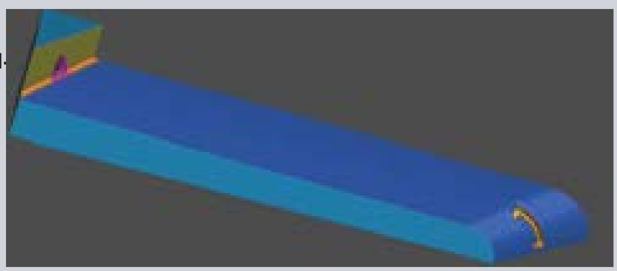
Tool-



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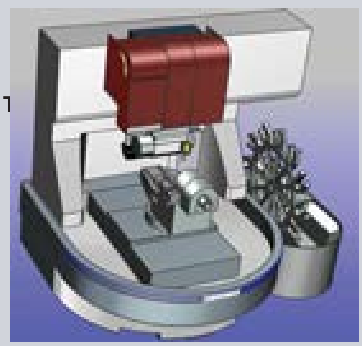
Machine T



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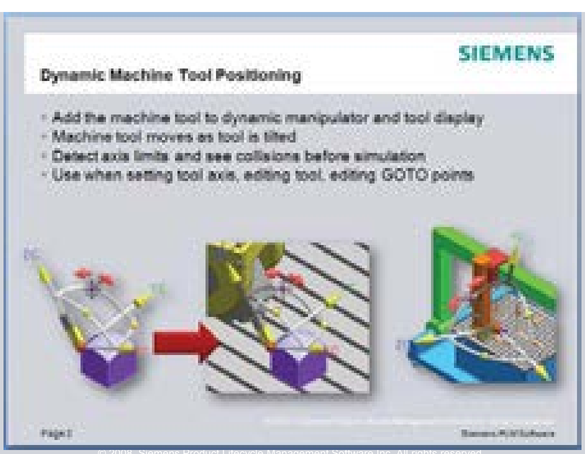

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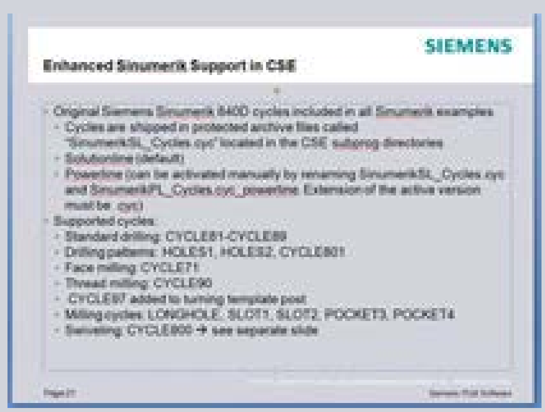

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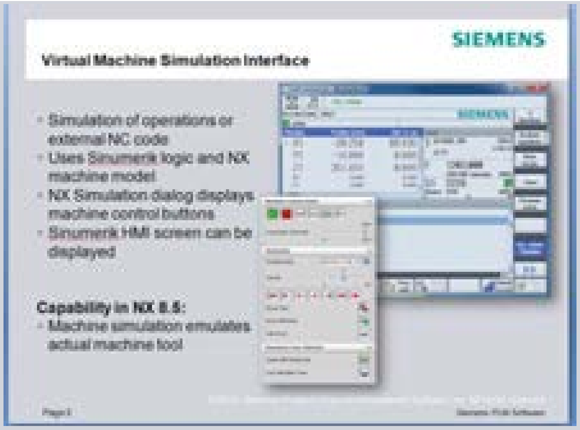

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DNC - Shop Floor Connect.

Manages All Shop Floor Activities

DNC
Mfg. Resource Management (Tools + Fixtures Etc..)

SIEMENS

NX/Open Programs.

- KBE.
- User Function (C, C++, VB, Java, Grip)

SIEMENS

Input Geometry:

Standards: STEP IGES DXF DWG
Cad Models: CATIA Pro-E S-works S-Edge SDRC
Others: JT Parasolid STL CGM
(*JT is a Light weight Model for Collaboration.)*

Extending the 3D Master to Manufacturing Information & Procedures

3DEXPERIENCE

Israel Flores
13 December 2013
MBE Summit, NIST

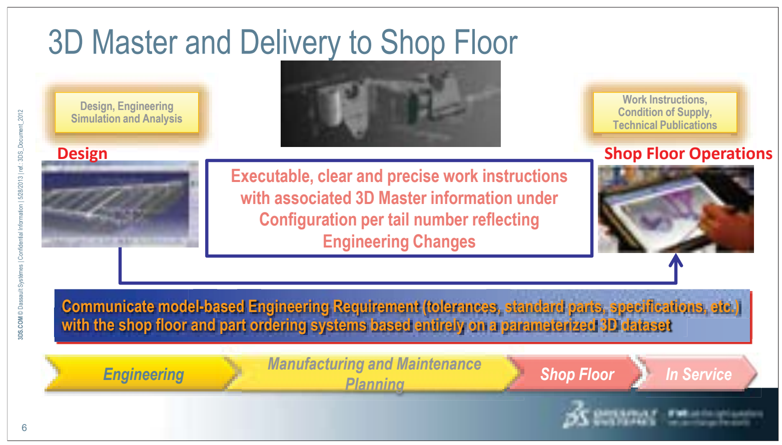
Agenda

- DS 3D Experience : 3D Master (Eng → Mfg)
- Openness and Data Exchange (STEP)
- Manufacturing Data Archiving


Our Legacy: from 3D-Design to 3DEXPERIENCE
3D - Design
3D-DMU
Digital Mock-Up
3D-PLM
Product Lifecycle Management
3DEXPERIENCE
V3 | 1986
V4 | 1994
V5 | 1999
V6 | 2009
3


Digital Product Definition → 3D Master
100% 3D definition
3D single reference
2D only a presentation
3D Design
2D Master
PAPER
DOCUMENTS
Today
3D Design
3D Master
3D Master Vision
4


3D As Master End-to-End Process Coverage
3D Work Instruction Authoring
3D Work plan Definition
3D Product definition
Dedicated Pre-study tool
Technical Publication
Manufacturing
Engineering
Production
Shop floor Review
Assembly Tolerance Analysis
Quality Inspection
Native Data
SUPPLIERS
Technical Publication
Customers
Authorities
Partners
Other contributors
5


3D Master and Delivery to Shop Floor
Design, Engineering Simulation and Analysis
Work Instructions, Condition of Supply, Technical Publications
Design
Shop Floor Operations
Executable, clear and precise work instructions with associated 3D Master information under Configuration per tail number reflecting Engineering Changes
Communicate model-based Engineering Requirement (tolerances, standard parts, specifications, etc.) with the shop floor and part ordering systems based entirely on a parameterized 3D dataset
Engineering
Manufacturing and Maintenance Planning
Shop Floor
In Service
6


3D Master and Delivery to Shop Floor
Design, Engineering Simulation and Analysis
From Engineering:
Design annotations
FT&A
Work Instructions, Condition of Supply, Technical Publications
Design
Shop Floor Operations
From Manufacturing:
Manufacturing sequence / Routings
Assembly validation
Work instructions
Manufacturing views
Buy-off/Sign-off
Data collection fields
Quality checks
Engineering
Manufacturing and Maintenance Planning
Shop Floor
In Service
7


DS 3D Experience Solution
Design, Engineering Simulation and Analysis
Work Instructions, Condition of Supply, Technical Publications
Design Intent
Shop Floor Operations
Planning, Offline Programming, Simulation and Validation
Engineering
Manufacturing and Maintenance Planning
Shop Floor
In Service
Data Management
8

Agenda

- DS 3D Experience : 3D Master (Eng → Mfg)
- **Openness and Data Exchange (STEP)**
- Manufacturing Data Archiving

STEP selected for LOng Term Data ARchiving

- STEP is the DS strategic format for Long Term Archiving and Interoperability
  - STEP / ISO 10303 : dedicated standard for neutral Data exchange and Archiving
  - STEP evolutions are driven by customer consortiums : ProSTEP, PDES inc, LOTAR
- DS has a long experience with STEP
  - AP203 and AP214 available in V4, V5 and V6
- DS extends its support to STEP applicative data

Solutions : DS working together with LOTAR

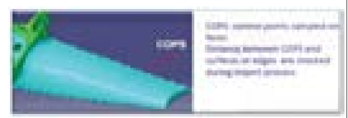
- **PMI as polylines : Cost Reduction**

Simplest and Most Reliable way to Achieve PMI for human interpretation

Solutions : DS working together with LOTAR

- **Validation Properties : Improve Transfer Quality**

1. Cloud of Points on Surfaces and Edges

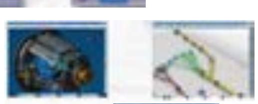


2. PMI (Polylines) : Length, CoG, and Validation String

Solutions : DS working together with LOTAR

- **New Technologies**:
  - Composites

  - Electrical



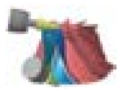
  - Manufacturing Process

Agenda

- DS 3D Experience : 3D Master (Eng → Mfg)
- Openness and Data Exchange (STEP)
- **Manufacturing Data Archiving**

Archiving Manufacturing Data

- APT and CL files not useful for archiving
- CAM to CAM transfer means recreation of NC
- A step in the right direction - V6 stores and links all manufacturing info.
- A neutral format would be welcome but not easy to create
  - Defining a standard could be the first step



Archiving Manufacturing Data

- How do we secure manufacturing data for long term archiving?
- STEP format?
  - Must be an industry effort that drives the solution.

IF WE™

Delcam

Engineering Data Exchange and the Manufacturing Supply Chain

One Vendor's View

Hanan Fishman
Director
Delcam Plc

Delcam's History

1960 & 70's Initial research at Cambridge University
Development taken over by Delta Group

1980 Software sales start

1990 Staff purchase company
New HQ, Birmingham, UK

1997 Delcam floats on UK Market

2002 10,000th customer 1st of 3 Queen's Award

2006 IMCS *(PartMaker)* joins Delcam

2007 25,000th Customer
End user sales exceed $100M

2009 30,000th Customer

Who Delcam are today

Our People
800 Staff
325 Within Overseas Subsidiaries
240 Within Joint Ventures
227 Software Development Group

What makes Us Unique
In house manufacturing facility
Nationwide/Worldwide training facilities
Local support
Delcam's Ownership Structure
Industrial Partners

Our Success
End user revenues over $100m
30,000+ Customers
60,000+ End users

Local Events
User Groups
Software Release Meetings
Technology Seminars
Press Conference
Regional Engineer Training Events
Inward Missions

Delcam Tooling Services

Delcam offers services for Toolmakers and manufacturers. The experience gained contributes to:

Development of a practical, efficient and cost effective software.

Co-ordination between the software development team and tooling services.

Provision of competitive contract services to our software customers.

Validation of new software releases and new product development.

Awarded ISO9000.

Return to Delcam Today

Delcam Training Courses

Proper training is essential to maximize the benefits of any CADCAM system.

Delcam offers comprehensive training in all its software, either at your local support office or on site.

PartMaker training offered across the country in Philadelphia, Chicago and Los Angeles

All training is given by experienced Delcam engineers.

Advanced courses are run for skilled users.

Monthly webinars are offered free of cost

Return to Delcam Today

Delcam Support Services

Delcam offers online & phone support for both software to all customers on maintenance.

All Philadelphia-based engineers have extensive CNC programming experience

Support is expert, local and highly efficient with "one click email support"

Experienced engineers can access and analyse problems on-line.

Upgrades and patches available from http://updates.delcam.com

Regular product release update seminars enable users to get to grips with new features rapidly.

Return to Delcam Today

Ownership

- Delcam's ownership is also a unique strength
  - Listed on the UK Stock Exchange providing oversight and discipline (DLC.L)
  - Renishaw is major external shareholder (20%)
  - Renishaw & Delcam's management team control the majority of the shares, creating a stable position and ensuring a long term perspective

Return to Delcam Today

CAM Partners

Return to Delcam Today

Offices Worldwide

Worldwide Support

Over 300 local support offices world wide

Manned by experienced engineers, local to you

Supported by a network of resources around the world

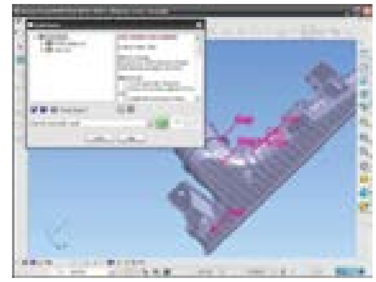
Select to find out more about Delcam in

North America | Europe | Russia | China
Latin America | Asia | India | Africa

Return to Worldwide Locations

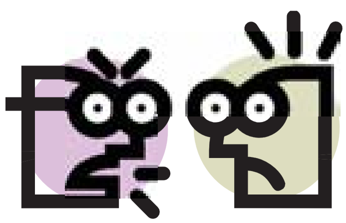
Data Translation Problems Affecting Your Supply Chain

- The data translation problem
- Why is it getting worse?
- Modeling Basics
- Data Repair – Solid Doctor
- Direct Modeling
- Conclusions



Data Translation

- Data translation is the same as translating languages
- Easy at the basic level
- Very difficult for complex or intricate details



What is football? – U.S. vs UK

- Two nations separated by a common language
- How do you spell mold (mould)?
- True Irony:
  - U.S. - Modeling
  - U.K. - Modelling

The cost of data translation

- In 1999, NIST estimated the cost of data translation to the automotive industry as over $1 billion
- 2008 report in MoldMaking Technology claimed:
  - 90% of toolmakers receive less than half of models in their preferred format
  - 42% of toolmaking companies use four or more CAD systems each month

How are the costs incurred?

- Cost of data translation software
- Cost of time needed to repair models
- Cost of time to confirm repairs are correct
- Cost of maintaining multiple CAD systems
- Cost of hiring or training staff to operate multiple systems
- Cost of translating files to return to customer

CADCAM and the supply chain

- Some promote the concept of a single system for the whole supply chain
- This won't work because:
  - OEMs and Contract Manufacturers use different systems
  - OEMs change the systems they use
  - New versions of "same" system aren't compatible
  - Disappearing CAD systems, e.g. CADDS and SDRC

The "best" software

- No software is the "best" for everything
- The needs of the OEM manufacturer are not the same as those of the contract manufacturer
- Being the best at data management and product design does not make you the best at NC programming
- OEMs can afford to pay more for software than smaller contract manufacturers

The problem – Part complexity

The problem - Productivity

- All industries are looking to shorten product development times as faster new product introduction increases profitability
- Companies that are second to market want to shorten the time gap
- Time taken to solve data translation issues increases product development times

The problem – Data reuse

- Companies are looking to increase design productivity by modifying existing products
- Data translation issues are a major problem according to Longview Advisors
  - Only 14% of designers receive their data in the required format, even in the same company
  - 8% never get their data in the required format

The problem - Litigation

- Buyers are more likely to sue suppliers
- OEMs are more likely to pass the problem on to suppliers

The problem - Longevity

- Aircraft built 50 years ago are still flying
- Aircraft built today will still need replacement parts for the rest of this century

The problem - Traceability

- OEMs, especially in areas like aerospace and medical applications, need to provide complete traceability on their parts
- Data must be transferred back up the supply chain if any changes are made to the design
  - Fillets added or altered to improve flow in the mold
  - Draft angles changed to ease removal of the part from the mold

Modeling Basics

Wireframe

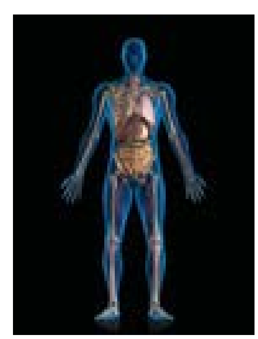
- Lines
- Arcs
- Curves
- Highly rigid and mechanical
- Basically 2D

Surfaces

- Created with longitude, laterals, and trim boundaries using wireframe and curve geometry
- Individual pieces
- Highly malleable and flexible, but have no volume
- Typical neutral formats
  - IGES
  - STP/STEP

Solids

- Groups of surfaces to create one piece
- Contains history tree in native format
- Have volume



Solids

What is a dumb model?

Definition: A solid model without any "history" or perhaps one converted to a surface model such as IGES or STEP

Why should you care?

- Designers may not want to send outside manufacturers their actual native files for concern of IP piracy
- Designers don't want to send out more information than they have to get the part made
- Designers often don't know how a part will be made – i.e. machined, cast, molded, pressed etc.

Standard formats

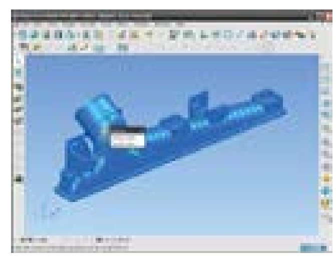
- Standard formats are promoted, especially IGES, STEP and Parasolid
- IGES is like ice cream, very nice but comes in many flavors

Model Repair

- Solid Doctor

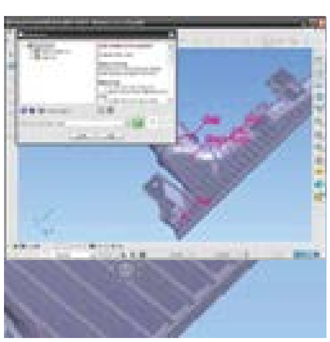
Data Repair Solution

- Software (part of CAD and reverse engineering) that can read and repair CAD models
- Converts CAD files into valid, high-precision Solid models
- Typical problems solved are:
  - Gaps/overlaps
  - Duplicated/missing surfaces
  - Poor quality trimming
- This requires solid and surface modeling options



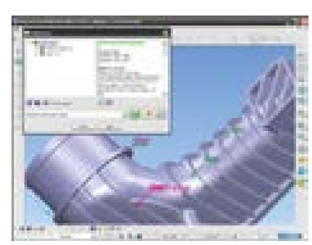
Stage 1 – Highlight the problems

- Analyses the model and labels all the problems



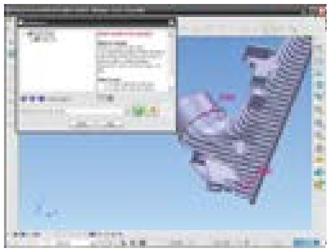
Stage 2 – Automatic repair

- Automatic repair tools fix the simpler problems
- Solid modeling tools used to match edges exactly
- Labels are turned green as problems are fixed



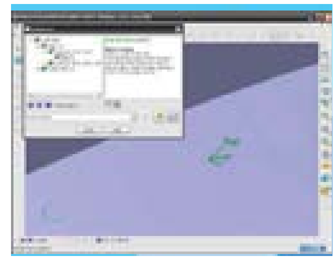
Stage 3 – Complex problems

- Remaining problems keep red labels
- Repair methods are suggested using surface modeling tools



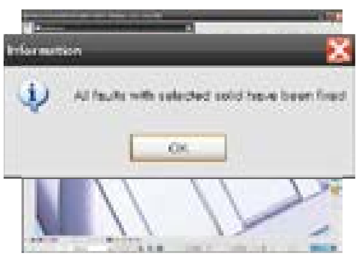
Stage 4 – Re-trimming

- A common problem comes when surfaces aren't trimmed correctly
- This can be corrected by editing boundaries



Stage 5 – Replace surfaces

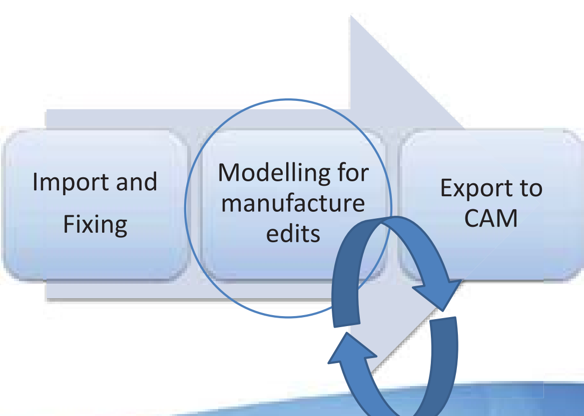
- For the most complex problems, surfaces must be deleted and replaced
- Surface modeling can fill the area with a surface tangent to adjoining areas



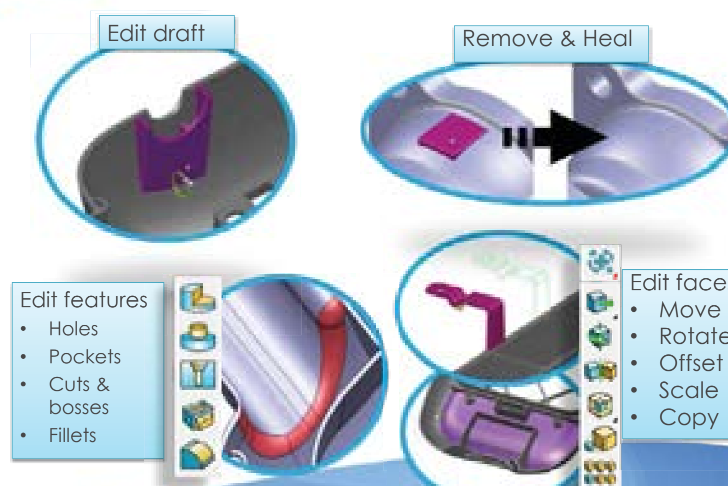
What is Direct Modeling?

- Ability to make rapid, history free edits to solids
- Surrounding faces automatically extend and re-intersect
- Maintains a closed solid

What does Direct Modelling mean to Delcam?

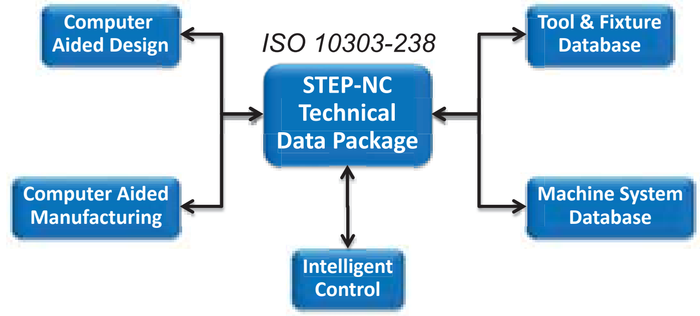


Direct Modeling



Conclusions

- Lack of CAD compatibility is a major problem for manufacturing industry
- Using the same system along the supply chain is not the answer
- A combination of solid and surface modeling tools provides a quick, easy way to work with models created from any CAD system through to manufacturing



CAM to CAM Data Exchange

STEP Tools, Inc.
http://www.steptools.com

Martin Hardwick
MBE Summit – 2012-12-13

Contracting for manufacturing assemblies

OEM		Supplier		Who?
Assembly Requirements	+	Manufacturing Resources	=	Manufacturing Process

- **How to reduce costs by cooperating?**
  1. If OEM owns the process (by owning the resources) then the solution is more expensive (traditional solution)
  2. If supplier owns the process then the solution is more time consuming (recent aerospace solution)
  3. If OEM and supplier share the process then solution is less expensive and less time consuming (CAM Data Exchange solution)

Unnecessary costs

OEM assembly constraints — *Repeat for every Supplier* — *One shop solution*

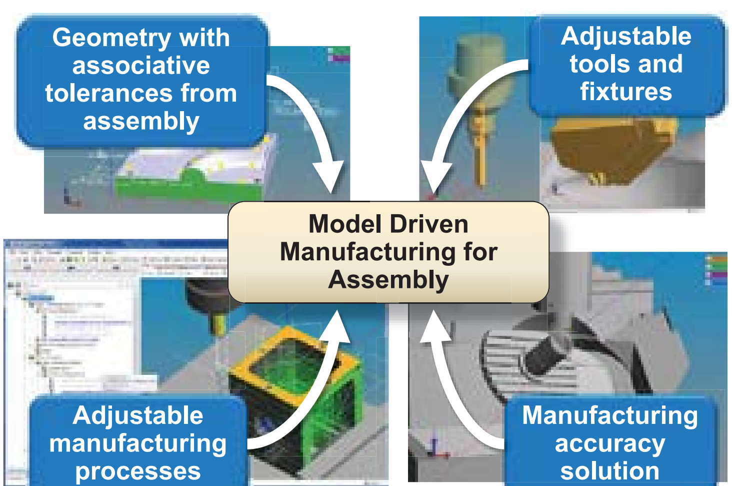
CAD —IGES→ CAM —Gcode→ CNC

One machine
One setup
One tooling

Weak automation — *No interoperability*

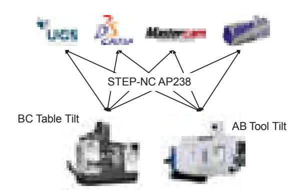
- **Visits to suppliers to explain models**
- **Maintenance of additional machines**
- **Repetitive, error prone data entry**
- **Misunderstandings over drawing symbols**
- **Incomplete simulations**

Desired solution – Science not Art

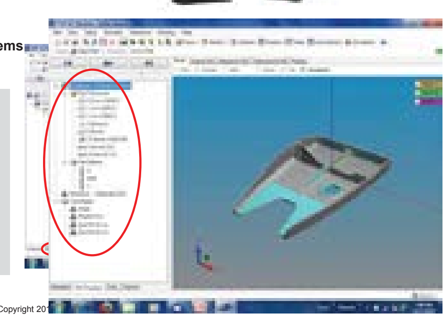


What is ISO 10303-238 STEP-NC?

- **New information to make machining faster and more accurate**
  - Supply chain interoperability
  - On machine feed-speed/tool-wear optimization
  - On machine simulation and collision detection
  - Closed loop machining and measurement
  - Feature based
  - Platform independent
  - Full fidelity simulation
  - Plug and play with CAD and CAM systems



- STEP-NC describes "what" not "how"
  - Make this geometry from this stock
  - By removing these features
  - In this order
  - With these tolerances
  - And tools that meets these requirements
- The old standard described "how"
  - Move tool to this location
  - Move tool to this location
  - And so on for millions of commands



How do we know - 10 years of testing

Phase	Demonstration Dates	Capabilities Shown	Application
1	November 2000 February 2002 January 2003 June 2003	Tool path generation from manufacturing features	Cost estimate automation
2	February 2005	CAM to CNC data exchange without post processors	Interoperability
3	May 2005 June 2006 July 2007	Integration of machining and measurement	On machine acceptance
4	December 2007 March 2008 October 2008	Cutting tool modeling Cutting cross section modeling	Resource and performance optimization
5	May 2009 September 2009 June 2010 October 2011 June 2012	Tool wear modeling Machine tool modeling Closed loop compensation Accuracy prediction	Just in time tooling

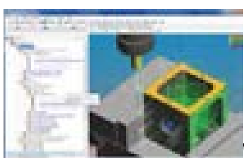
Projected Benefits*

- 35% reduction in preparation costs for routine machining
- 50% reduction in costs for engineering changes
- 50% reduction in inspection costs
- 90% reduction in drawings
- 20% increase in value of CAM solutions
  - New shop floor applications (e.g. adaptive fixturing)
  - Increased usage of advanced functionality (e.g. feed/speed automation)
  - Access to a much larger database
  - Support for a long term archive data format

*by Organization for Machine Automation and Control (OMAC)

Path to Deployment – Starting Jan 2013

Boxy STEP-NC file (www.steptools.com)



2nd 6 months

Operation Reader — CAM

ISO 10303 -238 STEP-NC

CAM — Operation Writer

1st 6 months

STEP-NC Explorer

View & Verify

Boxy part in aluminum or steel

CAM to CAM data exchange for a 3 axis part

Summary

- STEP-NC defines a technical data package for manufacturing
  - Portability and Interoperability for manufacturing
  - Enable many new automation applications
  - Faster communication, fewer errors, more accurate simulations
  - Decade of testing, ready for deployment
- Industry projects large process savings and significant increased value for CAM systems
- Join us!
  - Make a Boxy
  - Translate to STEP-NC
  - Participate in testing forum

DOE/NNSA
Kansas City Plant

Model-Based Quality Metrology
Enabled by Quality Information Framework Interoperability

One of Two Key Technology Enablers Required for
Smarter Manufacturing in MBE

Curtis W. Brown, P.E.
Principal Mechanical Engineer

Model-Based Enterprise Summit
December 11, 2012

The Kansas City Plant is Operated by Honeywell FM&T for the United States Department of Energy under Contract No. DE-NA0000622

We make products for national security.

Overview

- Safety Message
- What is the Kansas City Plant / Honeywell FM&T?
- Model-Based Quality Metrology Requirements
  - Interoperability Standards enable MBE
    - Dimensional Metrology Standards Consortium
    - Quality Information Framework
    - Product Definition + PMI (GD&T)
  - Features Reduce Complexity
  - Smarter Model-Based PMI
- Some Big Ideas and Request for Involvement

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Kansas City Plant
M&O Honeywell FM&T

Established by DOE in 1949 with over 3.2 million ft^2, 2800+ people
- Classified Secured Facility

- Managed and Operated by Honeywell Federal Mfg. & Technology (FM&T)
- Primary Mission: Build & Sustain Non-Nuclear Portions of the Nuclear Arsenal
- Engineering & Manufacturing are Primary Core Competency's - very diverse capabilities
- Responsible to provide (make and/or purchase) 100,000 + items for DOE
- Mission includes partnering with
  - Companies and Other Government Agencies
    - Work for Others (WFO) Program; and/or
    - Companies – Cooperative Research & Development Agreement (CRADA)

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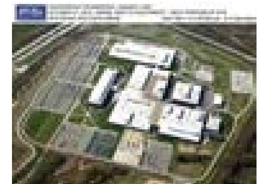
Plant Relocation

- **Kansas City Plant for NNSA nonnuclear production is moving.**
- **Honeywell proposed a multifaceted transformation in Dec, 2005.**
- **Kansas City Plant transformation strategic thrust areas:**
  - Reduce oversight
  - Strategic sourcing and sizing
  - Business process transformation
  - Creation of a new, modern, agile facility
- **Together these changes will:**
  - Reduce footprint by at least 50%
  - Reduce costs by 25% ($100M annually)
  - Maintain current mission performance
  - Provide Flexibility for future mission needs
- **Provides an infrastructure that is more responsive to potential changes in technical capabilities and schedule demands.**
- **Move Starts in Dec, 2012 from the Bannister Federal Complex, Kansas City, MO**
- **Move Completed in May 2014 to the National Security Campus, Kansas City, MO**



MBQM Critical Requirements

- **Fully Semantic Product Tolerance Representation**
- **Domain Specific Shape Features**
- **Digital Interoperability Standards**
  - **Product Definition Plus PMI**
  - **Quality Information Framework**
    - **Dimensional Metrology Standards Consortium**
    - **MBQM Workflow**
    - **Validation & Demonstration**
    - **Measurement Results**
      - **Dimensional**
      - **Attribute**
      - **Non-Dimensional**
      - **Real-Valued**
    - **Metrology Resources**
    - **Measurement Rules**
    - **Process Plans**
    - **Part Programs**

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Quality Information Framework What is it?

High level view

QIF is a standard integrated information model for the **real-time exchange** of data between software and equipment modules in quality measurement

- Standard ⇒ Open development, free-to-implement, free tools
- Integrated ⇒ No overlap, harmonized upstream
- Information model ⇒ XML Schema (W3C)
- Application Data Files ⇒ Conform to QIF data model
- Actual interfaces ⇒ Actual market use case
- Software/equipment modules in the quality measurement process ⇒ Plan, Program, Execute, Analyze

QIF developed within the Dimensional Metrology Standards Consortium (DMSC)

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Dimensional Metrology Standards Consortium DMSC

- A non-for-profit, cooperative sponsorship organization with **members Large and Small**
- Focused on or relating to Digital **Dimensional Metrology**
- Dedicated to identifying, promoting, fostering, and encouraging the **Development and Interoperability of Standards** that benefit the dimensional metrology community.
- An **ANSI accredited Standards Making organization** with **ISO fast-track** international presence
- Brought you the **DMIS ISO Standard**, the most influential standard in the industry
- Ensure that metrology standards fill gaps and do not overlap

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Dimensional Metrology Standards Consortium DMSC

- Response to 2006 **Metrology Interoperabilty Roadmap**
- Introducing the **Quality Information Framework** (QIF)
  - A **suite of integrated XML Schema-based standards**
  - Enabling the seamless flow of information for digital quality measurement systems
  - **Emerging** as an American National Standard (CY2013)
  - **Progress** as an ISO fast tracked Standard
  - www.qifstandards.org
- Preparing a complementary XML Schema-based **Product Definition with Product Manufacturing Information** (PMI) solution
  - Intent to submit for standardization

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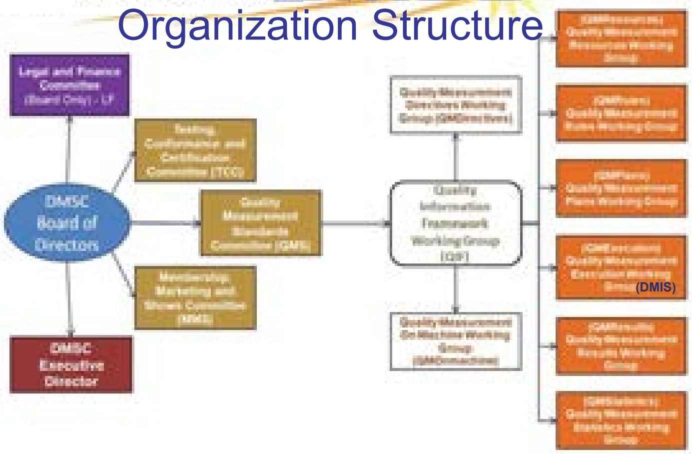
Dimensional Metrology Standards Consortium DMSC

Organization Structure



Driving Technology and Innovation through Standards

Kansas City Plant

Dimensional Metrology Standards Consortium DMSC

- **DMSC Consortia Members**
  - Applied Automation Technologies
  - Capvidia
  - Deere & Company
  - Hexagon Metrology
  - Honeywell FM&T
  - Lockheed Martin
  - Origin International, Inc.
  - MetroSage
  - Metrology Integrators
  - Mitutoyo America Corp
  - Nikon Metrology
  - NIST
  - PAS Technology
  - Renishaw
  - Siemens PLM Software
- **Working Groups**
  - **Open to all who have a Direct and Material Interest**
  - Rolls Royce
  - Pratt Whitney
  - GE Aviation
  - Boeing
  - DISCUS Software
  - Zeiss
  - Renaissance Services

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Dimensional Metrology Standards Consortium DMSC

In Summary, the DMSC can:

- Define Standard Interoperability Exchanges within a Model-Based Quality System
- Provide the holistic mechanism to **establish national and international standards.**
- **Foster** authorized **groups** (committees, work groups).
  - to promote and/or develop specifications into standards.
  - to maintain and/or enhance existing standards
  - to coordinate and harmonize related standards.
- **Encourage collaboration** of efforts to achieve shared goals.
- **Increase profits** for DM vendors & manufacturers!
  - Saves You and your QIF enabled vendors Time and Money

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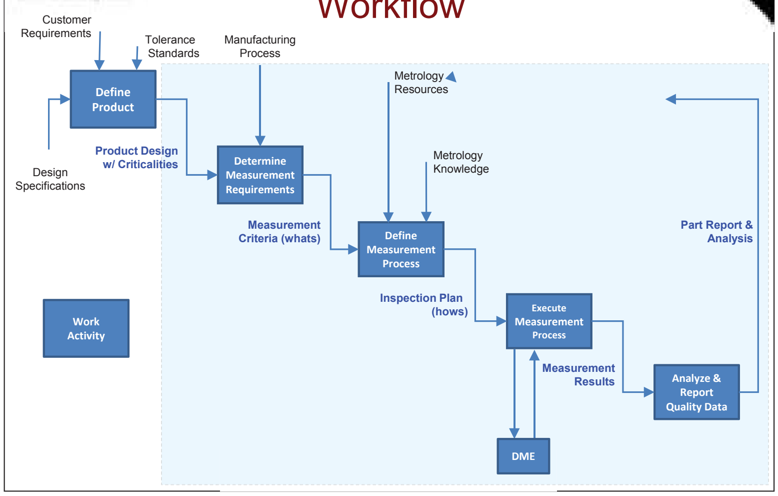
Model-Based Quality Metrology Workflow



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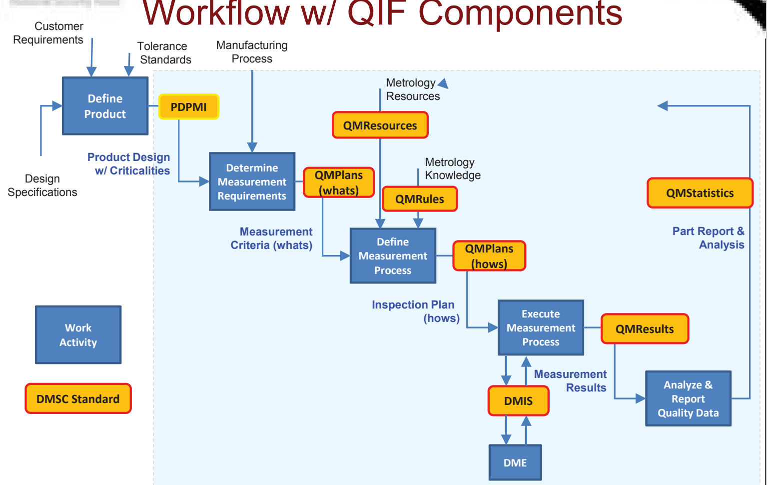
Model-Based Quality Metrology Workflow w/ QIF Components



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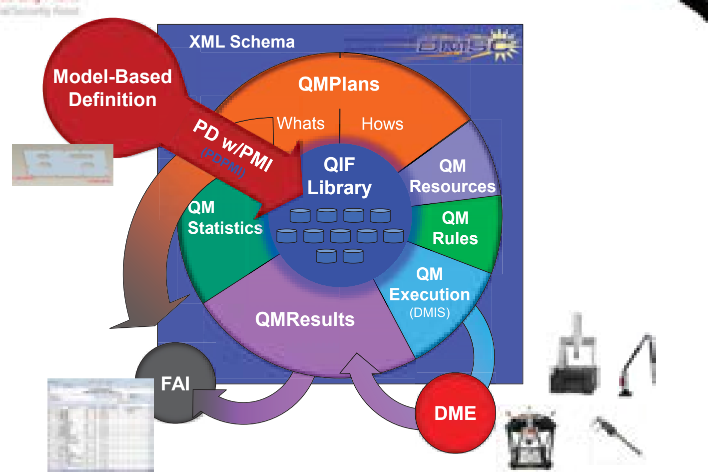
DMSC's QIF LifeSaver Slide



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Why XML Schema Files are Used

XML Schema

- XML Schema (.xsd) has adequate expressive power: types, derived types, built-in data types, constraints, inclusion, etc. are provided.
- There is a default data file format (XML) for data files governed by XML Schemas.
- XML Schema is a widely accepted language, and its data file format is even more widely accepted.
- Tools for processing XML schemas and XML data files governed by schemas are available free or at a moderate price.
- Lower cost investment for application implementers.

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QIF Model Suite

QIF Library Models

Eleven Schema Models

QIF Application Schema Models **(uses the QIF Library)**

- **QMPlans v1.0 (whats)**
- **QMResults**
- QMResources
- QMRules
- QMPlans v2.0 (hows)
- QMStatistics
- QMExecution (NG-DMIS)

Product Definition w/PMI

- PDPMI

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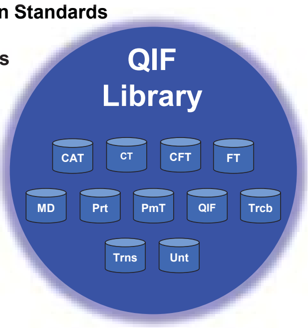
QIF Library

- **Common Quality Data Framework**
- **Ensuring Interoperability between Standards**
- **XSD Schemas Files for**
  - **Characteristic Aspects Types**
  - **Characteristic Types**
  - **Constructed Feature Types**
  - **Feature Types**
  - **Measurement Devices**
  - **Part Types**
  - **Primitive Types**
  - **QIF Types**
  - **Traceability**
  - **Transforms**
  - **Units**
- **Support QIF Application Models**
- **Benefits**
  - **Avoid Multiple Definitions**
  - **Avoid Conflicting Definitions**
  - **Eliminate Point-to-Point Harmonization and Mapping with other specs.**



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Metrology Requires Features

QIF Feature Types

QIF Feature	DMIS Equivalent	QIF Feature	DMIS Equivalent
Arc	ARC (format 1)	Line	LINE
Attribute	OBJECT (possibly)	Pattern	PATERN
Circle	CIRCLE	Plane	PLANE
Composite		PointDefinedCurve	GCURVE
Compound	COMPOUND	Point	POINT
Cone	CONE	PointDefinedSurface	GSURF
ConicalSegment	CONRADSEGMNT	Slot2D	CPARLN
ExtrudedCrossSection	*no equivalent*	Slot3D	PARPLN
Cuboid	RCTNGL	Slot3DWithDraft	SYMPLN
Cylinder	CYLNDR	Sphere	SPHERE
CylindricalSegment	CYLRADSEGMNT	SphericalSegment	SPHRADSEGMNT
EdgePoint	EDGEPT	SurfaceOfRevolution	REVSURF
Ellipse	ELLIPS	ToroidalSegment	TORRADSEGMNT
ElongatedCylinder	ELONGCYL	Torus	TORUS

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Tolerances are Characteristics

QIF Characteristics

CharacteristicBaseType
- CharacteristicAspectBaseType
  - DimensionalCharacteristicAspectBaseType
    - AngleCharacteristicAspectBaseType
    - AngularCharacteristicAspectBaseType
    - LengthCharacteristicAspectBaseType
    - LinearCharacteristicAspectBaseType
  - GeometricCharacteristicAspectBaseType
    - FormCharacteristicAspectBaseType
    - LocationCharacteristicAspectBaseType
    - OrientationCharacteristicAspectBaseType
    - ProfileCharacteristicAspectBaseType
    - RunoutCharacteristicAspectBaseType
  - UserDefinedAttributeCharacteristicAspectType
  - UserDefinedVariableCharacteristicAspectType

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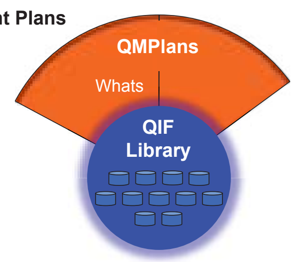
QMPlans

Actions

Quality Measurement Plans
- **XML Schema File**



- **Standard format for Defining Measurement Requirements (i.e., the “whats” that need to be inspected)**
- **Identify Measurement Features**
- **Their Characteristics (e.g., Tolerances)**
- **Criticality**
- **Measuring Sequence**
- **Scalable**
- **Extensible**

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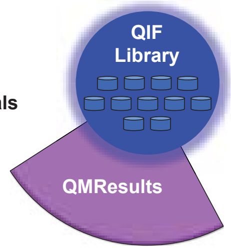
QMResults

Quality Measurement Results
- XML Schema File
- Standard format for Representing Measurement Results
- Dimensional
- Non-Dimensional
- Point data
- Fit Features to data
- Feature Actuals
- Characteristic Actuals
- Pass/Fails



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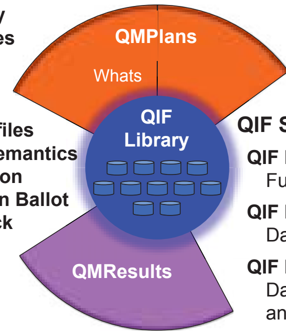
First Phase of Standardization

QIF V1.0

QIF V1.0 Deliverables
- QIF Common Library
  - Eleven Schema Files
- Application Models
  - QMPlans.xsd
  - QMResults.xsd
- XML Schema (.xsd) files
- Data Structures & Semantics
- April, 2013 Completion
- ANSI Standardization Ballot
- Future ISO Fast Track



QIF Standard Parts for ANSI

QIF Part 1: Overview and Fundamental Principles of QIF

QIF Part 2: Library Data Model, Data Structures and Semantics

QIF Part 3: QMPlans Application Data Model, Data Structures and Semantics

QIF Part 4: QMResults Application Data Model, Data Structures and Semantics

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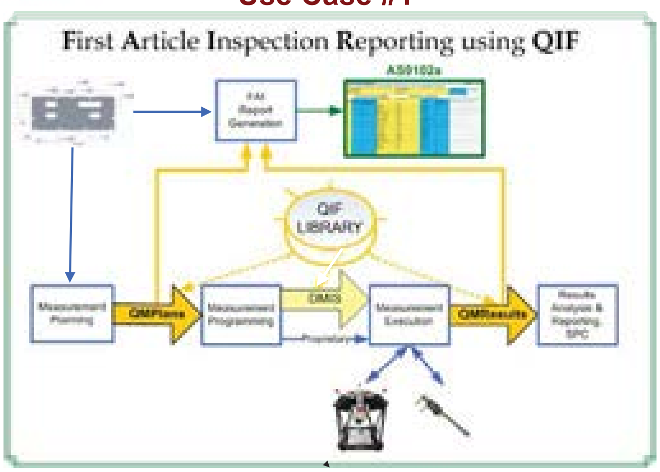
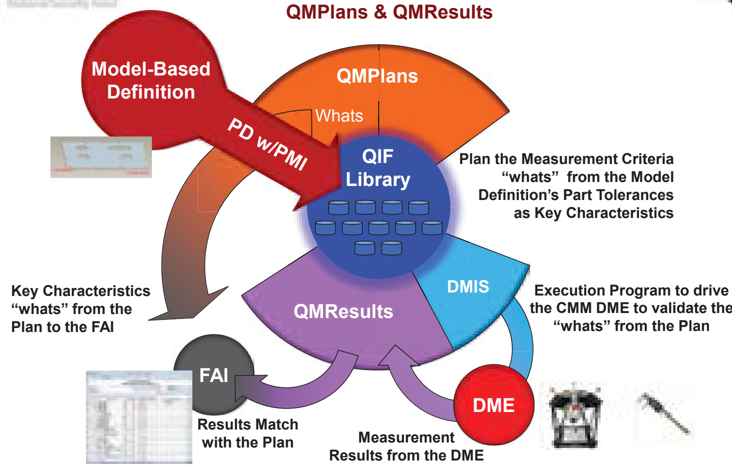
Validation thru Demonstrations

Use Case #1



IMTS 2012 QIF Demonstration

QMPlans & QMResults



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QIF Use Case #1 Demo

IMTS 2012 Participants

- Honeywell FM&T
- PAS Technology
- Mitutoyo America
- DISCUS Software
- Renishaw
- IPI Technology
- with
  - MTConnect Institute
  - NIST
  - Lockheed Martin

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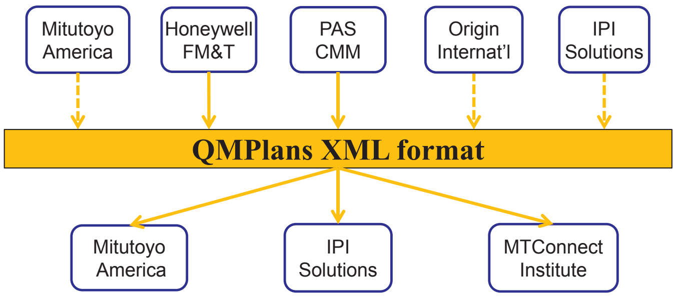
Multivendor Interoperability Output and Input of QMPlans



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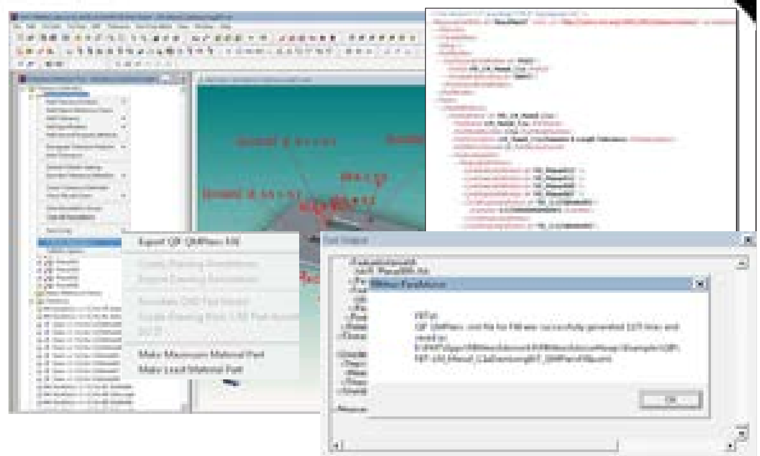
QMPlans from KCP's *FBTol*



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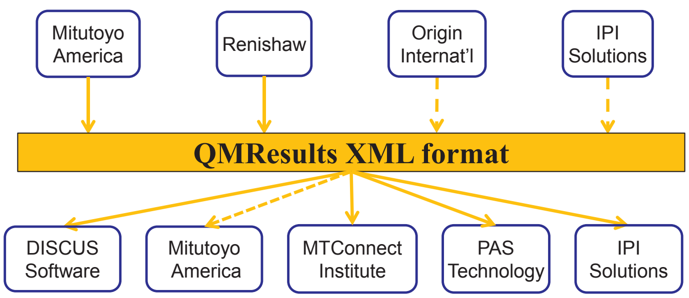
Multivendor Interoperability Output and Input of QMResults



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Press Release

Quality Community Impressed with QIF Interoperability Demonstration at IMTS 2012.

At the IMTS 2012 Show, the **DMSC, Inc.** successfully demonstrated the generation and population of an AS9102 First Article Inspection form as their first use case for the exchange of quality data via the emerging **Quality Information Framework (QIF)** national standard.

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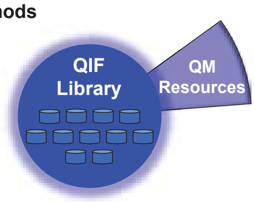
QMResources

Quality Measurement Resources
- **XML Schema File**
- **Standard format for Defining Measurement Resources**
- **Supports QMPlans w/Methods**
- **Measuring Equipment**
- **Sensors**
- **Rotary Tables**
- **Work Centers**



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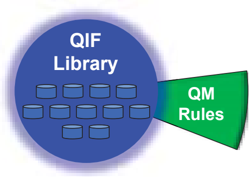
QMRules

Quality Measurement Rules
- **XML Schema File**
- **Standard format for Defining Measurement Rules**
- **Supports QMPlans w/Methods**
- **Point Measures**
- **Resource Selections**
- **Sampling Techniques**
- **Algorithms**



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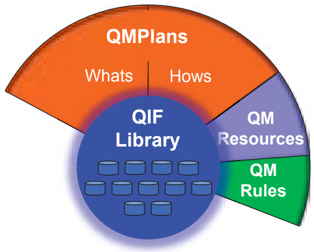
QMPlans

Methods

Quality Measurement Plans
•XML Schema File



•Standard format for
Defining Measurement Process (i.e., the "hows" it to be inspected)
•Assigns Resources
•Applies Rules
•Measuring Sequence
•Dimensional & Non-Dimensional
•Setup
•Algorithms

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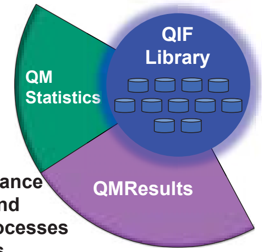
QMStatistics

Quality Measurement Results
- XML Schema
- Standard format for
  Analyzing Multiple Part Inspections



- Quality Control
- Identify Trends
- Assess Performance
- Judge Quality and
- Efficiency of Processes
- Trace Anomalies
- Provide Feedback
- Improve Production

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MBQM Critical Requirements

- Fully Semantic Product Tolerance Representation
- Domain Specific Shape Features
- Digital Interoperability Standards
  - Product Definition Plus PMI
  - Quality Information Framework
    - Dimensional Metrology Standards Consortium
    - MBQM Workflow
    - Validation & Demonstration
    - Measurement Results
      - Dimensional
      - Attribute
      - Non-Dimensional
      - Real-Valued
    - Metrology Resources
    - Measurement Rules
    - Process Plans
    - Part Programs

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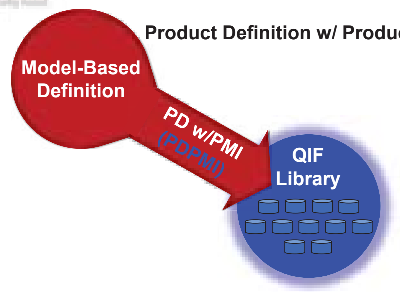
PDPMI

Product Definition w/ Product Manufacturing Information
- Native CAD + PMI
- STEP AP242



- XML Schema Files (via Newly Proposed DMSC/Capvidia MoU)
  - Standard format for Exchange of Product Definition w/ PMI (PDPMI)
  - Product Definition (e.g., Solid Model)
  - Various Conformance Levels of Semantic PMI (GD&T)
  - Easier Use and Implementation
  - Satisfy CAD to Model-Based Metrology Use Case and more….
  - Satisfy STEP to Model-Based Metrology Use Case and more….

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Issue Statement

Quality is a ***customer requirement*** and it is ***<u>not optional</u>***.

Unfortunately, even with the successful emergence of model-based definition, our Metrology Community ***has not realized*** the benefits promised by this investment.

Two primary contributions:

- ***Standard digital interoperability*** needs of the community as being addressed by the ***QIF***.
- ***Successful exchange*** of model-based product definition along with PMI data in a ***cost effective*** standard-based manner, as being addressed by proposed MoU.
  - CAD Data via XML
  - ***STEP AP242*** via XML

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Statement of Intent

- Pursue a Memorandum of Understanding (MoU) for **collaborative development work**.
- DMSC – a not-for-profit standards developing consortium
- Capvidia – a private engineering software developing company
- Capvidia will **donate** a set of XML Schemas from their CAP.**XML data format**, which pertains to the rich, mature, and multiple **representation** of 3D **Model Based Definition with PMI**.
- DMSC Working Group will:
  - **Harmonize Contribution** with its QIF
  - Progress and Prepare for ANSI Standardization
- Expected Outcome is an **XML-based exchange solution** for **Product Definition plus PMI** (PDPMI) that **satisfies** the **Industrial use cases**:
  - CAD to Metrology *as well as CAD to Manufacturing*
  - **STEP** to Metrology *as well as STEP to Manufacturing*

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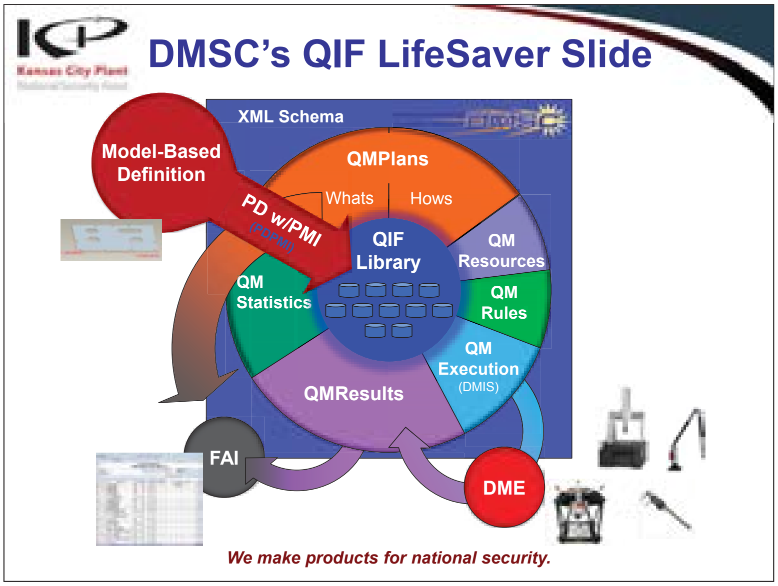


E-3327 IMTS 2012

VERISURF
3D Measurement Solutions

Model Based Inspection: Leveraging Model Based Definition for Quality Assurance

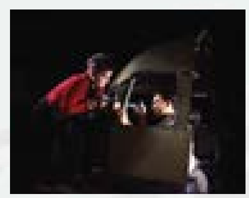
Presented by: Ronald Branch, Product Manager

Definition of MBD

Model Based Definition(MBD) also known as **digital product definition** (**DPD**), is the practice of using 3D digital data (such as solid models and associated metadata) within 3D CAD software to provide specifications for individual components and product assemblies. The types of information included are geometric dimensioning and tolerancing (GD&T), component level materials, assembly level bills of materials, engineering configurations, design intent, etc. By contrast, other methodologies have historically required accompanying use of 2D drawings to provide such details.

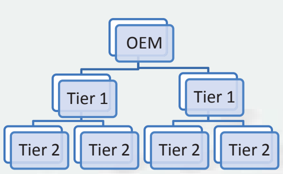
Origins of MBD

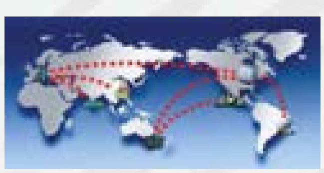
MBD has developed from the globalization of aircraft manufacturing and extended product lifecycle of aircraft. In the past aircraft companies were vertically integrated and manufactured most the aircraft components. Most had large machining centers and stretch forming plants, some even had their own foundries.



Origins of MBD

Today major OEM's are reshaping their business models to be that of airframe assemblers and are outsourcing part and sub-assembly manufacture across a global supply chain. OEM's realize they need a process that will reduce time-to-market and improve product quality while communicating all the required design intent.





NIST - Simon Frechette

"The central concept embodied in MBD is that the 3D product model is the vehicle for delivery of all the detailed product information necessary for all aspects of the product life cycle."

Terrence McGowan Boeing Corp.

- "The 3D model should contain everything needed from design to manufacturing, in particular, GD&T."
- "The use of a 3D (spatial) process and product definition that represents and communicates 'purposed' design intent in 3D form to any downstream production and/or consumer utilization."

Boeing D6-51991 MBD

A Boeing dataset containing the exact solid, its associated 3D geometry and 3D annotation of the product's dimensions and tolerances to specify a complete product definition. This dataset does not contain a conventional 2D drawing.

Model Based Definition provides a single-source of definition, and it reduces conflict between CAD and paper drawings

www.verisurf.com

MBD Implementation Levels

Courtesy of Model Based Enterprise

www.verisurf.com

Value of MBD

- With authority bestowed on the model, MBD will:
  - Eliminate errors that result from referencing an incorrect source.
  - Make processes more efficient—no more searching to determine correct revision levels.
  - Eliminate outdated drawings floating around the manufacturing floor.
  - Eliminate discrepancy between the CAD model and 2D documentation.

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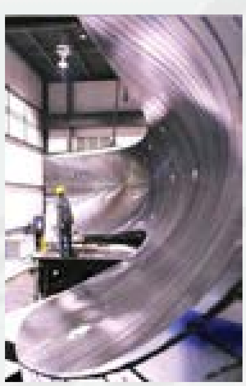
Goals of MBD

- Accelerate time-to-market (Reduce the Manufacturing lead times.)
- Decrease time and expense (Reduction in wasted manpower, more certainty on the shop floor, reduction of scrap and less time waiting for answers.)
- Improve quality (Better and Quicker answers and more involvement throughout the whole manufacturing process.



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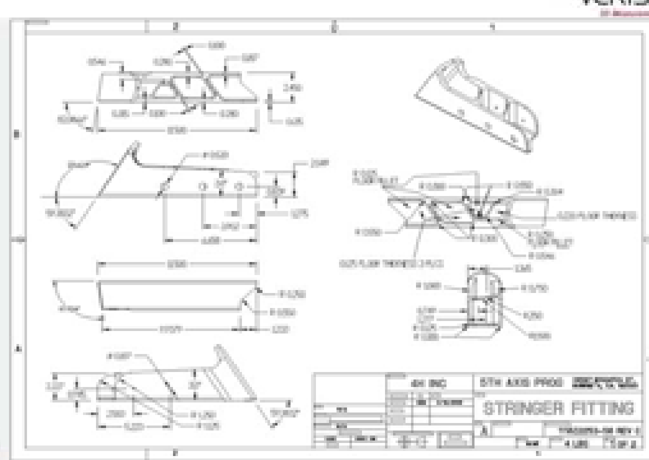
Companies Less Profitable using 2D Drawings.



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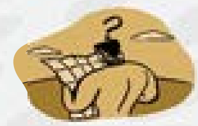
Lean concept for Six Sigma Inspection

- TIMWOOD – The 7 Wastes
- **Transportation** – Are you moving parts to/from inspection?
- **Inventory** – Is your inspection work in progress high?
- **Motion** – Do inspection people and equipment move efficiently?
- **Waiting** – How much lag time is there between inspection steps?
- **Overproduction** – Are inspections taking to long?
- **Over-processing** – Do you inspecting too many times or inefficiently?
- **Defects** – Are you making inspection mistakes and are you catching mistakes?

Lean Inspection Practices

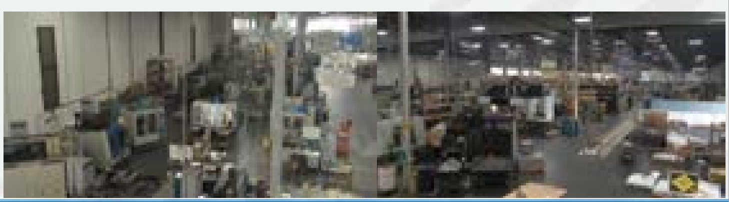
- Eliminate drawing waste with Adoption of Model Based Inspection Methods
  - Drawing creation (2-6 hours)
  - Drawing paper and printing (1-4 Hours)
  - Drawing based inspection (2-10 Hours)
  - Ambiguity or Uncertainty waste (1-100 hours)





Lean Inspection Practices

- Eliminate setup and alignment waste by inspecting parts they are still in their fixtures (Currently Most Manufacturing Plants have Inspection on side of the plant and everyone has to go back and forth 30 machines -150 hours/week)
- Eliminate waste of final inspection dependency (Integrate in process inspection into daily activities. Catch possible production problem before they get out of hand ????)

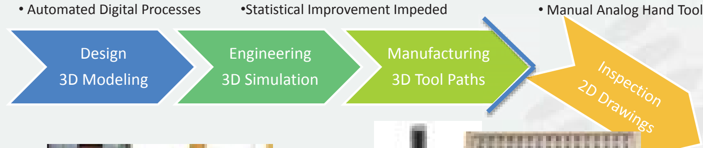


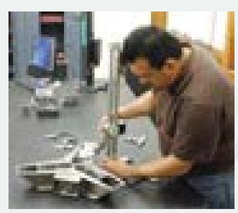
Model Based Definition Broken with 2D Drawings

Model Based Definition
- 3D Solid Models
- CAD Intelligence Utilized
- Automated Digital Processes

Model Based Definition Broken
- Productivity Barrier
- Quality Data Loop Broken
- Statistical Improvement Impeded

Drawing Based Definition
- 2D Drawings
- CAD Intelligence Lost
- Manual Analog Hand Tools






Inspection Process 2D Verses 3D

- Traditional Inspection Drawings
  - 2D drafting & blueprint reading
  - Non-Lean, large batch, isolated CMM's, serial processes
  - Stationary CMM inspection technology
  - 100% inspection
- Modern Inspection MBI
  - 3D Model based definition & inspection
  - Lean inspection processes
  - Affordable portable inspection technology
  - Key characteristics inspection

Benefits of Model-Based Measurement and Inspection

- No 2D Drawings
  - Cost and time eliminated
  - Contradictions removed
- Automated inspection planning
- Automated report formatting
- Accuracy
  - All features included in plan
  - No interpretation errors
  - GD&T rule checking
  - No data entry errors
- Prompted inspection procedures
- Live, graphical measurement display
- Automated reporting
  - No data entry
  - No manual calculations
- Only basic skills needed
- Eliminate CMM overhead (PCMM)
  - No fixtures
  - No part set-up
  - No programming
  - No manual data recording

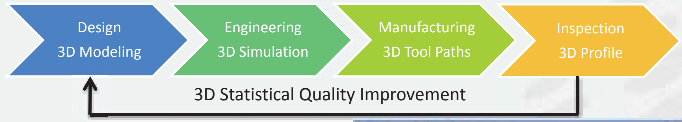
Companies More Profitable with 3D MBD

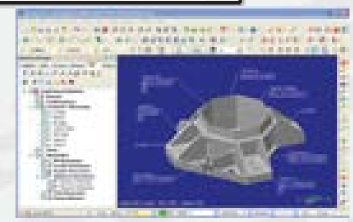
Model Based Definition Extended

Model Based Definition
- 3D Solid Models
- CAD Intelligence Utilized
- Automated Digital Processes

Model Based Definition Extended
- Productivity Improved
- No 2D Drawing Waste
- 3D Quality Data Loop Closed

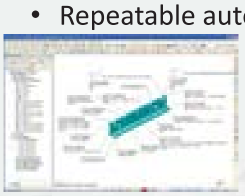
Model Based Inspection
- 3D Profile with Tolerances
- CAD Intelligence Utilized
- Automated Digital Process

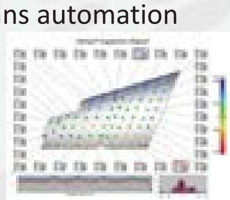




MBI Software Needed Capabilities

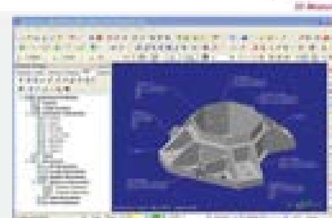
- Intuitive 3D CAD/CAM interface
- Import and inspect to any 3D CAD model
- Import or define MBD and GD&T
- Colorful graphical results display
- Concise inspection reports
- Repeatable automated inspection plans automation





MBI using MBD (3D GD&T)

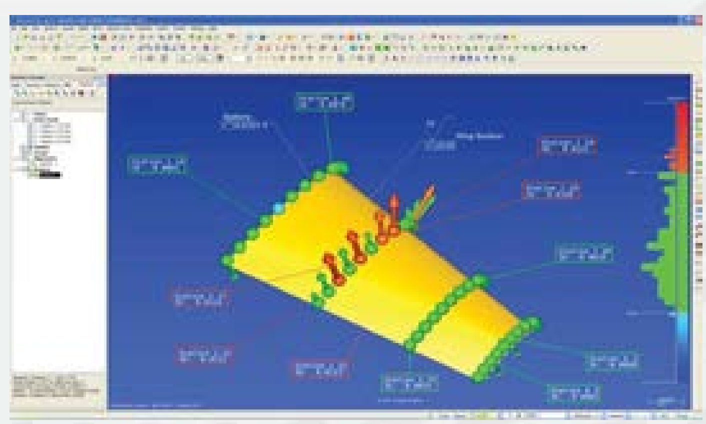
- Import MBD
- Create MBD
- Align to MBD
- Inspect to MBD
- Report to MBD



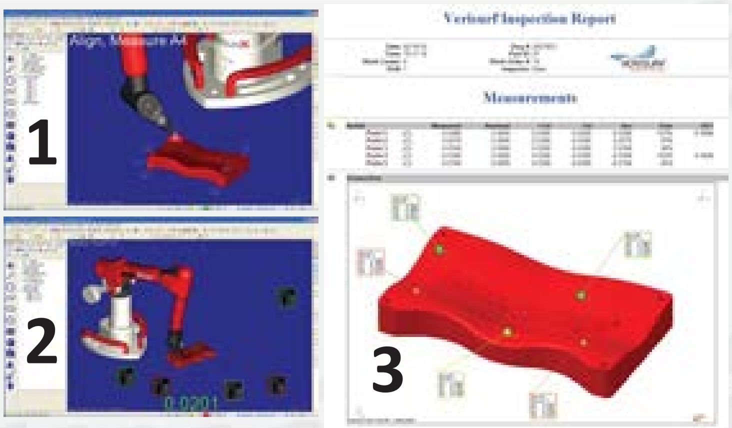
MBI Software Interpretability

- CATIA – Dassault
- UG - Siemens
- Pro/ENGINEER - PTC
- SolidWorks - Dassault
- Inventor - Autodesk
- SolidEdge - Siemens

MBI Graphics Display



MBI Inspection Process (3 Steps)



MBI Types Of Inspections

- On Machine
- In Process
- First Article
- Incoming
- Final

MBI Inspection On The Machine

- Check Set-ups
- Maintain Alignments
- Fast First Articles

3 COMPONENTS TO LEVERAGE MODEL BASED INSPECTION

PEOPLE PROCESS TECHNOLOGY

People

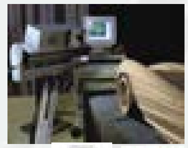
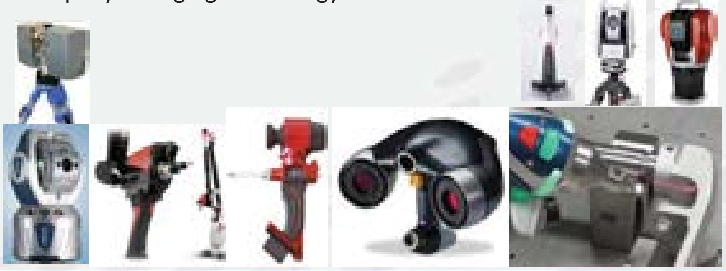
- Aging Workforce
- Developing New Talent
- Diminishing Supply of Manufacturing Skilling
- Personnel is key to remaining competitive
- Keeping workforce current with Rapidly Changing Technology

Process

- Requirements for daily operations
- Assures Constancy, Predictable and Traceability
- Frequently an Auditable Requirement

Technology

- Non Contact (Laser Scanning, White Light, etc..)
- PCMM Improved Accuracy and Capabilities
- Imbedded 3D GD&T(MBD)
- Rapidly Changing Technology

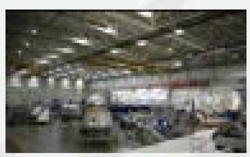



Predictions

- 3D Global Supply Chains
- Elimination of 2D Drawings
- STEP AP242 Will Enhance Interoperability
- Increased Noncontact Inspection & 3D Scanning
- Cloud Based Inspection Databases
- SPC of Key Characteristics

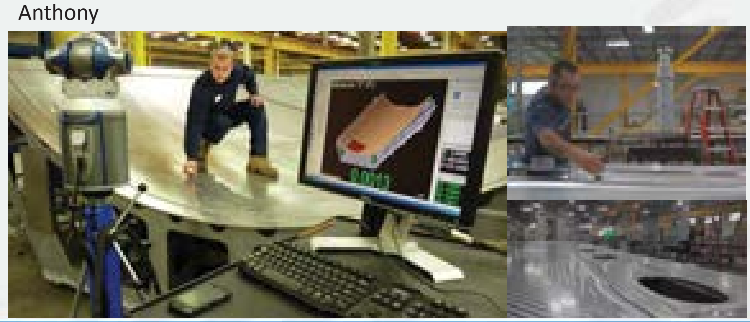
SpaceX – MBI Company

"Verisurf metrology software is doing its part in maintaining precision in the shop and on the launch pad. We use it for everything from tooling fabrication to pre-launch preparation" - Larry Mosse, Tooling Operations Manager


Coast Composites – MBI

"Verisurf and the laser tracker has allowed us to perform all the QA tasks we need to make our customers happy. The model tells you where it wants a hole or a part to be assembled and works perfectly to help us locate points on the mold to set details brackets, holes, you name it" – Steve Anthony

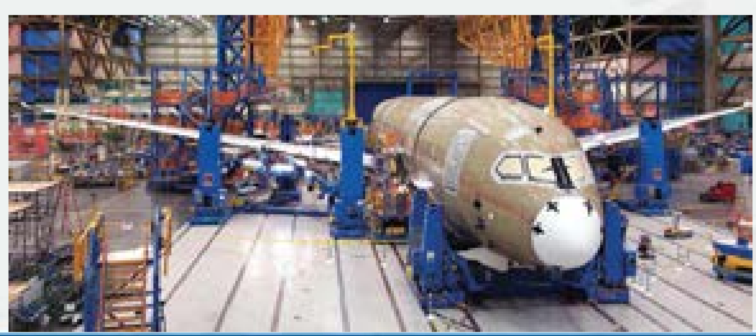


Vought – MBI

"With Verisurf, we set up our laser trackers, take our measurements and get on the spot analysis comparing the real product against the solid model. This gives us an instant and graphical error report". "We evaluated several software packages, and decided Verisurf was best suited for our needs" - Angel Diaz

AIT – MBI

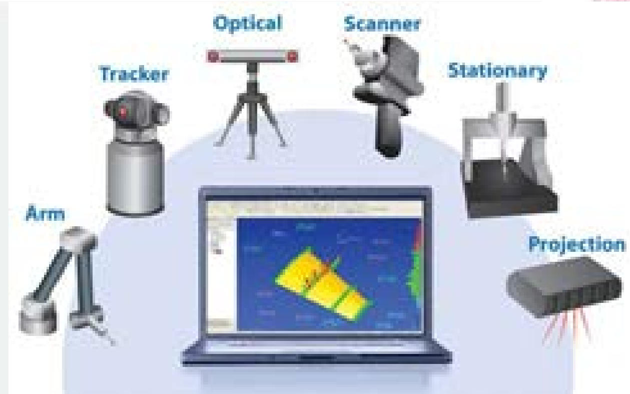
"To say AIT utilizes Verisurf X metrology software would be an understatement; AIT relies on Verisurf for virtually every aspect of our development and production workflow," Kempen, Quality Manufacturing Systems Manager, AIT.



US Navy – MBI

"We're trying to efficiently and effectively implement 3D MBI into the Navy system and Verisurf has been very helpful to us in that effort. Our goal is to keep US Navy F-18's flying, and Verisurf is a big help." Gabe Draguicevich, Engineering Technologist NAVAIR Advanced Measurement Systems and Reverse Engineering Lab

Devices used for MBI

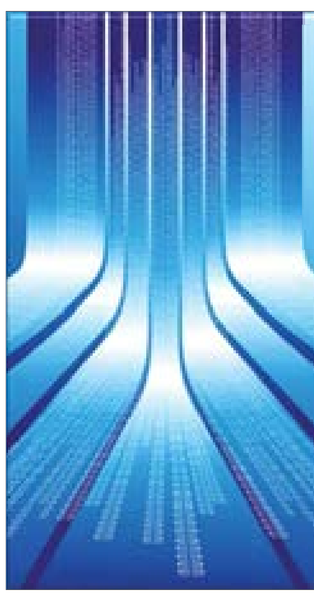


1. Contact Ron Branch
   1. Phone: 714-970-1683 ext. 136
   2. Email: ron.branch@verisurf.com
2. Learn about Verisurf www.verisurf.com
3. Visit our Booth E-3327

Verisurf Corporate Overview

- Verisurf Software, Inc. is a software development company located in Anaheim California
- Industries Served - Aerospace, Defense, Energy, Automotive, Heavy Equipment, Biomedical
- Applications - Manufacturing Inspection, Tooling Fabrication, Mold Making, Reverse Engineering
- Worldwide distribution through Mastercam Resellers

Born in Aerospace but Diversified Well Beyond



2012 Model Based Enterprise Summit

The Digital Future Today

Using open CAD formats to bridge the gap between today's and tomorrow's standards

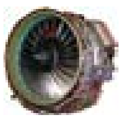
CAPVIDIA
Tomasz Luniewski

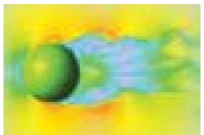
CAPVIDIA

- Founded in 1994 (Belgium, Russia, USA, China, Japan)
- Development of engineering software applications
- CAD data translation and CFD services
- 80 programmers & engineers (20% PhD)
- Name reflects company activities
  - Cap – capturing
  - Vidia – knowledge (Sanskrit)

Applications Areas:

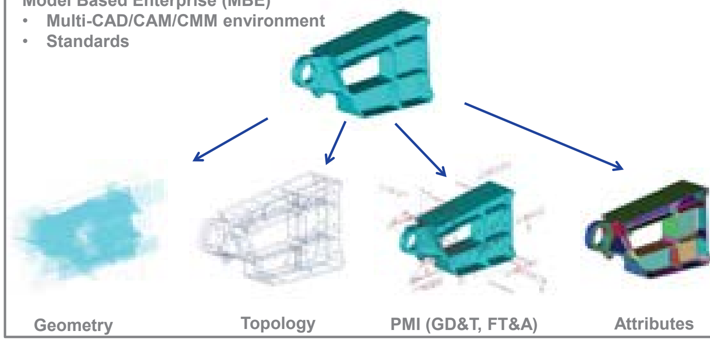
- 3D CAD data translation, validation, quality assessment
- CFD simulations - FlowVision





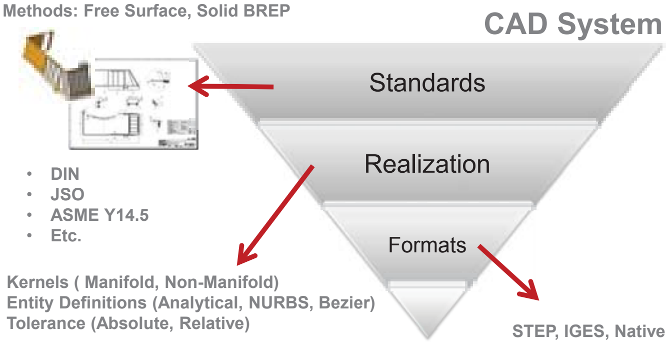

Model Based Definition (MBD)

Model Based Enterprise (MBE)
- Multi-CAD/CAM/CMM environment
- Standards



Standards Today

Methods: Free Surface, Solid BREP

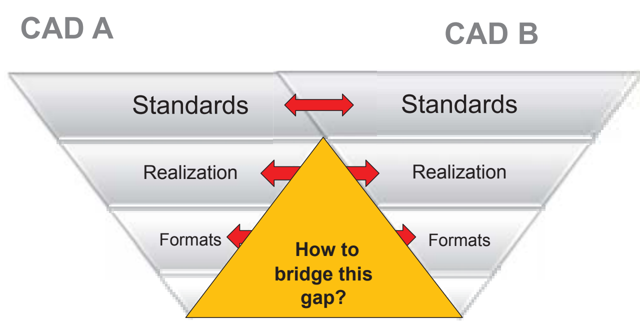


- DIN
- JSO
- ASME Y14.5
- Etc.

- Kernels (Manifold, Non-Manifold)
- Entity Definitions (Analytical, NURBS, Bezier)
- Tolerance (Absolute, Relative)

STEP, IGES, Native

CAD systems cmpability



Interoperability Today

3D CAD *visualization*
- 3DXML
- 3DPDF
- JT
- STL, VRML, etc.

3D CAD *data exchange* (native CAD formats, STEP, IGES)
- IGES, STEP - 3D Geometry/Metadata non semantic

Work in progress

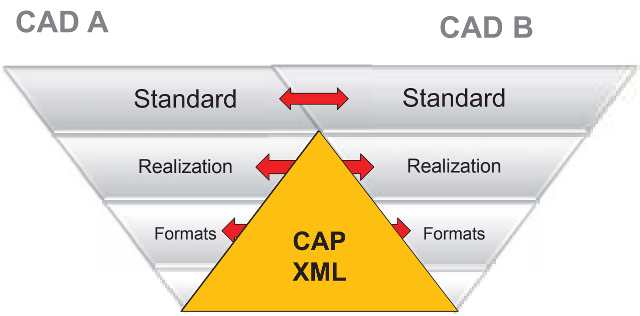
- STEP AP242 - 3D Geometry/Metadata semantic and non semantic
- STEP P28 - Data in xml format

MBE Challenges

Exchanging 3D geometry with metadata keeping semantic relations as they are defined in native CAD system

Provide open/standard based data exchange mechanisms for mainstream and downstream applications, production processes and long term archiving

Solution



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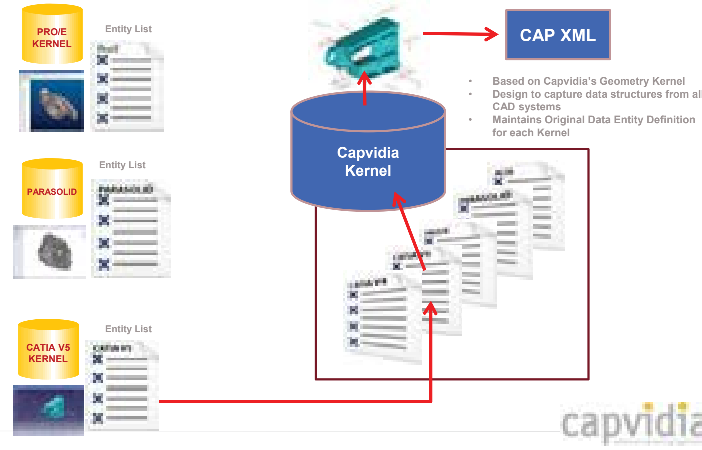
How we handle different native CAD data



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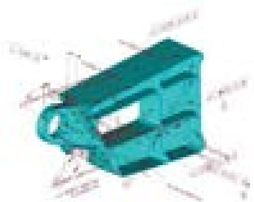
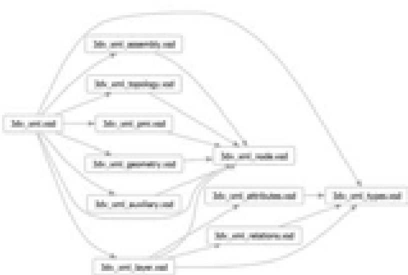
CAP XML Structure/Schemas

CAP XML schemas



NAS6606D27.CADPart
(Native Format)



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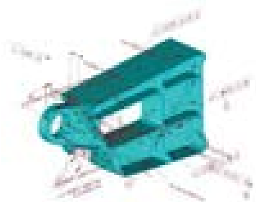
CAP XML Structure/Schemas

CAP XML format



NAS6606D27.CADPart
(Native Format)

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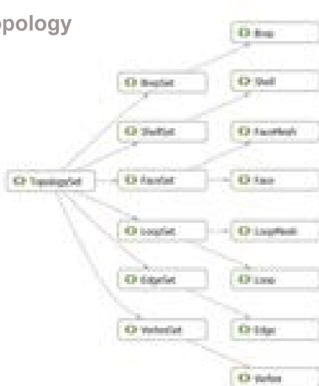
CAP XML Structure/Schemas

CAP XML format - Topology



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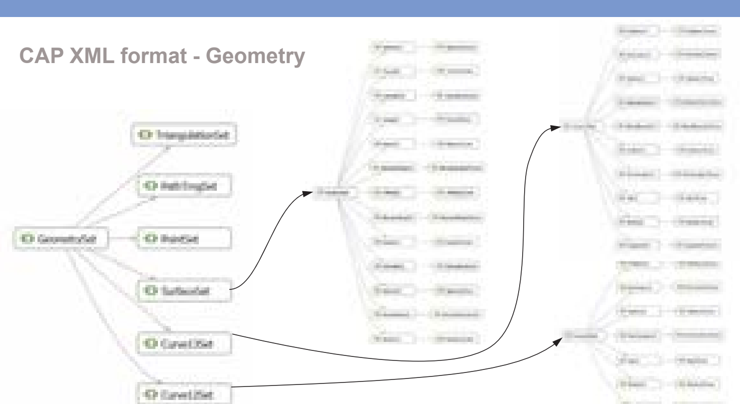
CAP XML Structure/Schemas

CAP XML format - Geometry



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CAP XML Structure/Schemas

CAP XML format - Attributes

In addition to the standard attributes a third part application can specify an arbitrary "custom" attribute (AttributeUser).

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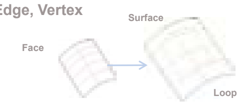
CAP XML Structure/Schemas

CAP XML schemas - Constrains

Using constrains in the xsd-schemas allows to specify certain restrictions on the values of the element (or attribute) and to establish a correct relationship between elements.

- BlockRoot – Layer
- BlockRoot, Block, Subfigure – Block, Subfigure, SubfigureInstance, Brep
- Brep – Shell, Face, Loop, Edge, Vertex
- Shell – Face
- Face – Loop, Surface
- Loop – Edge, Curve12



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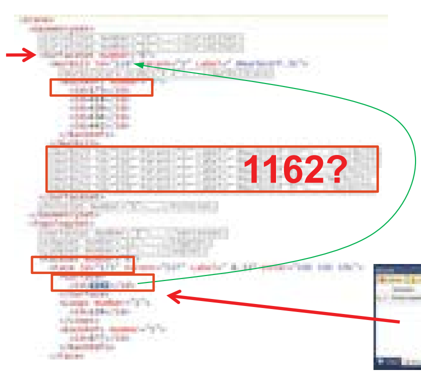
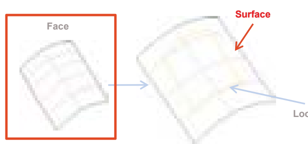
CAP XML Structure/Schemas

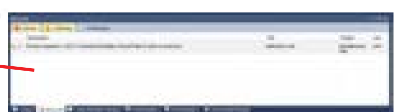
CAP XML schemas - validation example





Face must be connected with surface: Face/Surface/Id -> SurfaceSet/*/@id

Error: Face 175 is connected with an entity 1162 which is not presented in the SurfaceSet



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CAP XML Data Format

CAP XML format - PMI Metadata

- Roughness – roughness
- GTol – geometric tolerance
- Text – text annotation
- FlagNote – flag note
- Datum - datum
- DatumTarget – datum target
- Dimensions:
  - DimAng - angular dimension
  - DimLin – linear dimension
  - DimRad – radial dimension
- PartNote – part notes and standard notes

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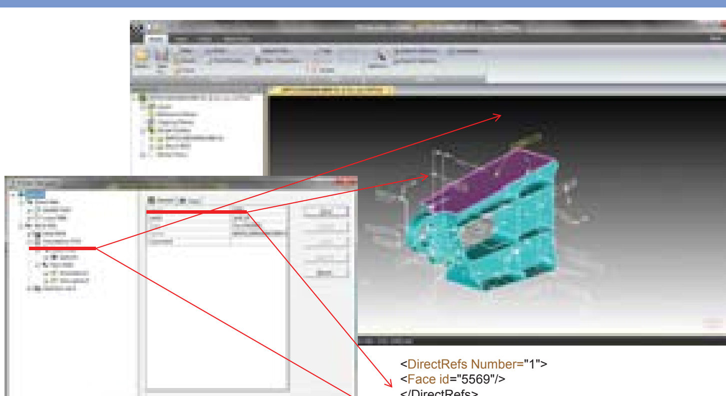
References/Semantics in CAP XML



<DirectRefs Number="1">
<Face id="5569"/>
</DirectRefs>
<BackRefs Number="2">5737 5738
</BackRefs>

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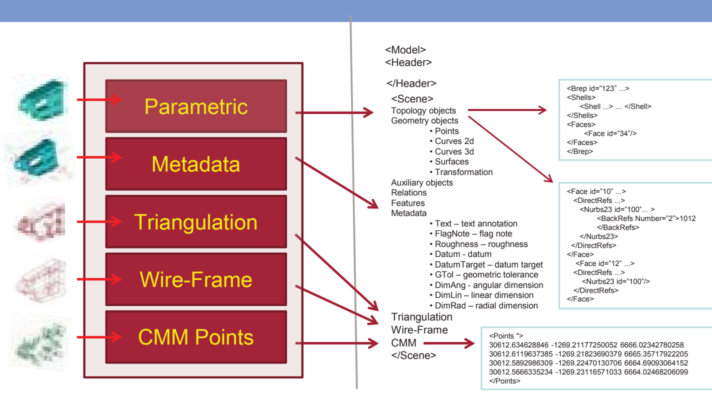
CAP XML – support of mixed model definition



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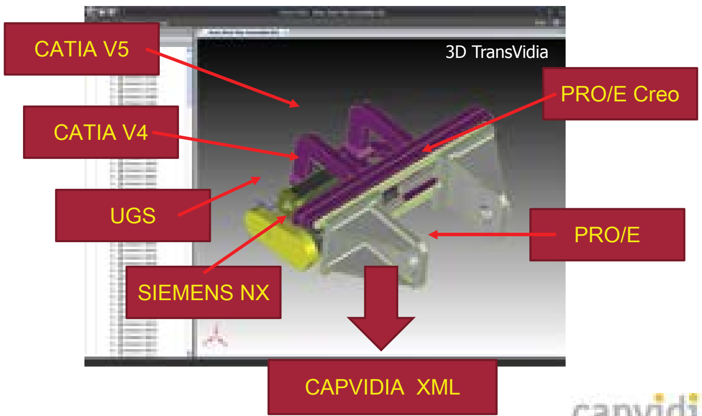
CAP XML – support of mixed model definition



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Integration with CMM software

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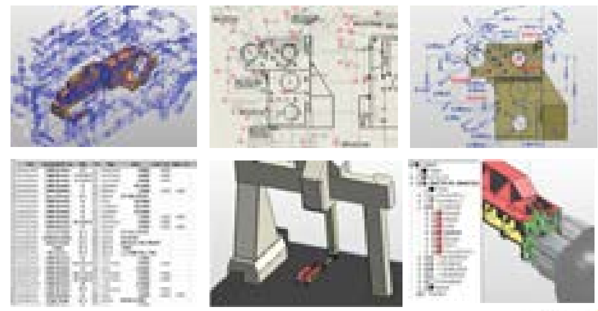
CMM Programming Automation



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Summary

Benefits CAP XML:

- Open XML format
- Human and machine readable
- Flexible and easy to extended
- Used for over 10 years in Capvidia applications
- Covers well all CAD systems structures
- Compact
- Bi-directional compatibility with STEP 242

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DMSC, Inc.

Statement of Intent
For Cooperation Under the Terms of a Memorandum of Understanding

The ***Dimensional Metrology Standards Consortium (DMSC, Inc.)***, a not-for-profit standards developing corporation, and **Capvidia**, a private software developing company, are pursuing a Memorandum of Understanding (MoU) for collaborative development work.

Capvidia will contribute to the DMSC a set of XML Schemas of their Open CAP-XML data format, which pertains to the exchange of Product Definition with Product Manufacturing Information (PMI) using the XML format.

In turn, the DMSC, as an ANSI accredited standards developing organization, will harmonize the contribution with its Quality Information Framework (QIF) as well as prepare and progress the contribution for national and/or international standardization.

The QIF is a suite of integrated XML Schema-based standards enabling the seamless flow of information within computer-aided quality measurement systems. Under the terms of the MoU, the expected outcome from this collaboration will produce an XML based exchange solution for product definition plus PMI that will not only satisfy the CAD to Metrology use case, but meet many other CAD to Manufacturing needs as well.

The final results of this collaborative effort is expected to be a submittal as an American National Standard, and later as an ISO Standard.

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METROSAGE

Model-Based Predictive Technologies for Dimensional Measurement

Jon M. Baldwin
Managing Partner
MetroSage LLC

METROSAGE

Outline

- What current model-based measurement planning (MBMP) does well.
- What current model-based measurement planning sometimes does.
- What model-based measurement planning could do well if it applied some existing technologies.

METROSAGE

What MBMP Does Well

- Enables partial concurrent measurement process planning.
- Enables "reasonable" measurement sequencing.
- Generates collision-free probe path.
- Facilitates sensor orientation selection.
- Somewhat automates probing point placement.

METROSAGE

What MBMP Sometimes Does

- Provides input and attachment of non-shape information (GD&T).
- Performance is extremely variable.
  - Dependent on user skill.
  - GD&T rules are often not well-enforced (if at all).
  - Measurement features are often not well defined.
  - GD&T attachment is often not robust.
  - Transfer between modeling systems can be problematic

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What MBMP Does Not Do

- Validate GD&T (complete, syntactically & semantically correct, non-redundant).
- Produce a measurement plan that is guaranteed to demonstrate traceability.
- Produce a measurement plan that is in any respect proven to be optimal.

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Tools to Alleviate These Issues

- Tolerance Scheme Validation
- Measurement Uncertainty Evaluation
- Cost of Measurement & Product Profitability Estimation
- Measurement Plan Optimization

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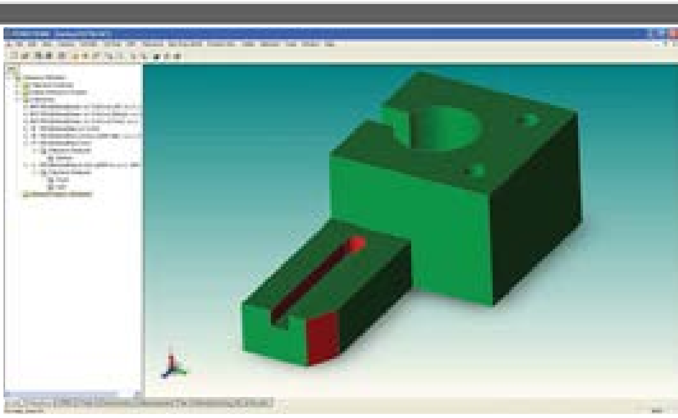
GD&T Validation



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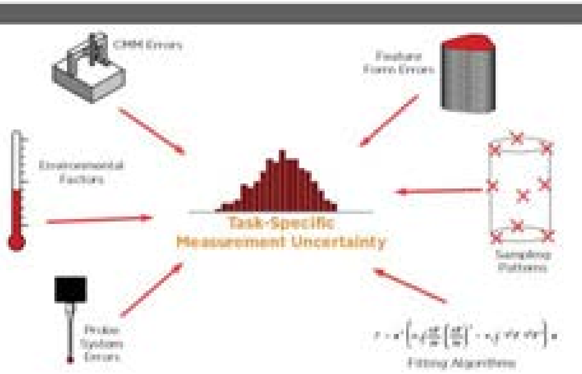
Measurement Uncertainty Evaluation



In addition, GD&T parameters measured on a CMM are often highly correlated and exhibit non-normal distributions.

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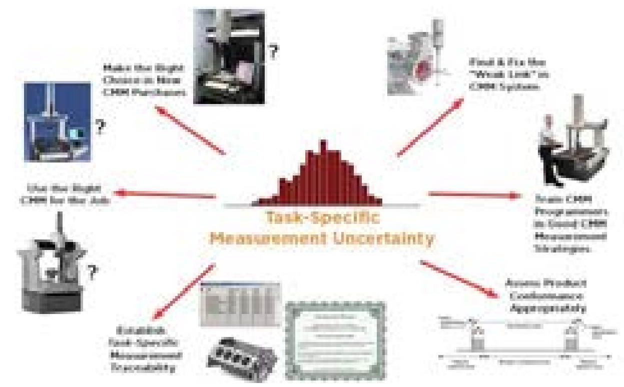
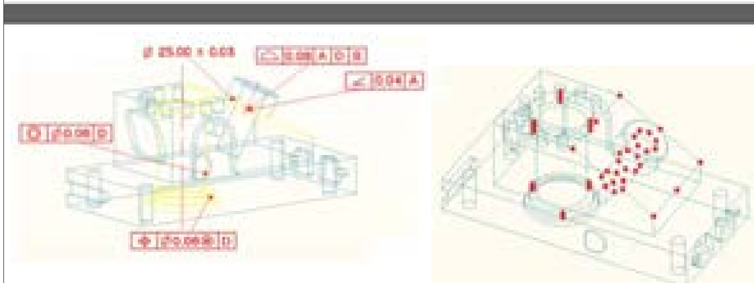
Motivations for Knowing Measurement Uncertainty



Strengths of Model-based Simulation Methods

- Can be applied to any part for which we have a model.
- Can simultaneously evaluate many GD&T parameters in one "experiment".
- Does not require knowledge of measureand interactions.
- Detects both measurement bias & variability.
- Predictive
- Economical

Example: Choosing the Right CMM



	Tolerance (µm)	4-to-1 Rule (µm)	10-to-1 Rule (µm)
POS 25.000d Hole	60	15	6
SIZE 25.000d Hole	60	7.5	3
ANGR wrt A Angled Face	40	10	4
PROF wrt ADB Angled Face	80	20	8
CONC wrt D 65.000dHole	60	15	6

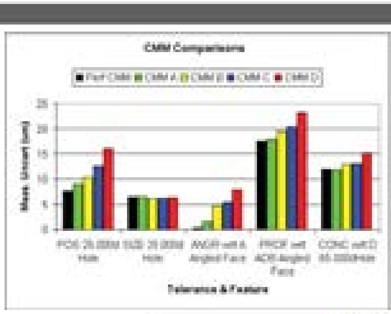
Example: Choosing the Right CMM

B89.4.1 Performance Test Data from Manufacturer's Data Sheets

	CMM A	CMM B	CMM C	CMM D
X-Linear Accuracy (µm)	1.2	3.5	5.7	8.5
Y-Linear Accuracy (µm)	1.2	3.5	5.7	8.5
Z-Linear Accuracy (µm)	0.91	3.2	5.3	8
Volumetric Performance (µm)	3	7.5	9	13.8
Offset Volumetric Performance (ppm)	5	12	15	24
Repeatability (µm)	0.8	4	4	6

	Perfect CMM	CMM A	CMM B	CMM C	CMM D
POS 25.000d Hole	7.7	9.1	10.5	12.4	16.1
SIZE 25.000d Hole	6.6	6.5	6.2	6.3	6.4
ANGR wrt A Angled Face	0.3	1.6	4.7	5.4	7.9
PROF wrt ADB Angled Face	17.4	17.8	19.4	20.4	23.2
CONC wrt D 65.000dHole	11.7	11.6	12.8	13	15.1

Example: Choosing the Right CMM



<u>Conclusions</u>:

None of the CMMs meet the 10:1 Rule for the measurement task of interest.

Based on the 4:1 Rule:

CMM D is clearly inadequate

CMMs B & C are questionable

CMM A meets requirements

4:1 Rule Results

	CMM A	CMM B	CMM C	CMM D
POS 25.000d Hole	9.1	10.7	12.4	16.1
SIZE 25.000d Hole	6.5	6.2	6.3	6.4
ANGR wrt A Angled Face	1.6	4.7	5.4	7.9
PROF wrt ADB Angled Face	17.8	19.4	20.4	23.2
CONC wrt D 65.000dHole	11.6	12.8	13	15.1

Measurement Risks and Costs

- There are two kinds of risk, each with an associated cost, associated with measurement errors.
  - There is a risk, α, and an associated cost of incorrectly classifying a good part as bad on the basis of a measurement error (Type I error).
  - There is a corresponding risk, β, and cost of incorrectly classifying a bad part as good on the basis of a measurement error (Type II error).

Measurement Error Costs

- Cost of a Type I error:
  - Cost of processing the item
  - Costs of reworking or discarding the item
  - Cost of un-needed process corrections
- Cost of a Type II error:
  - Cost of correction if discovered later in process
  - Costs if shipped to customer
    - Replacement cost
    - Cost of warranty pool
    - Loss of reputation or good will
    - Lawsuits

Production & Measurement

Economics of Measurement

Factors for Consideration:

- **Production Process Capability**
- **Measurement Process Capability**
- **Cost of Production**
- **Cost of Measurement**
- **Cost of Rejecting a Good Part (Type I Error)**
- **Cost of Accepting a Bad Part (Type II Error)**
- **Selling Price**
- **Loss Function**

Economics of Measurement

← More stringent acceptance More relaxed acceptance→

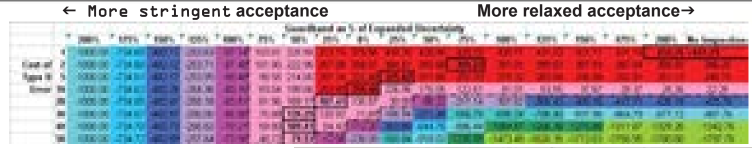
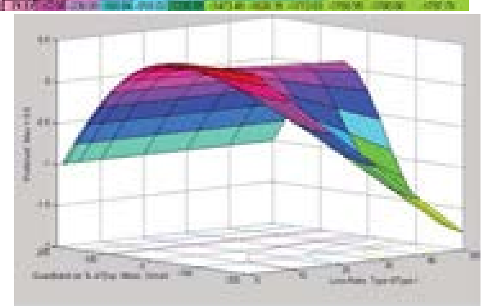


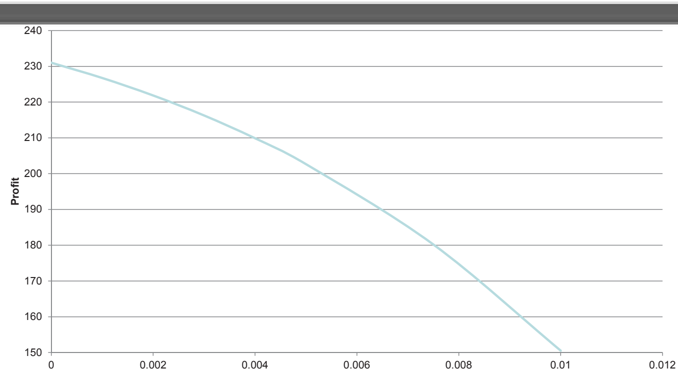
Table data for 1000 units

Risks of Type I & Type II Errors Depend on Cp, Cm & Guardbands

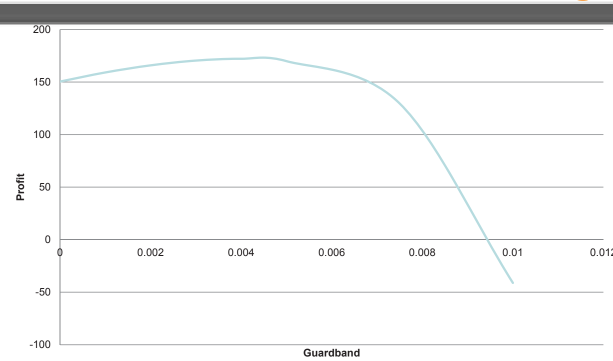
Optimized Guardband Depends on Loss Ratio of Type II/Type I Errors



Truly Optimized Measurement Processes – Production Bias



Truly Optimized Measurement Processes - Guardbanding



Model Based Definition

Enables

Inspection Lifecycle Management

Sam Golan
President & CEO
PAS TECHNOLOGY

November 2012

PLM – product lifecycle management

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise.

PLM – the "how"

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its **conception**, through **design** and **manufacture**, to **service** and **disposal**. PLM **integrates** **people, data, processes** and **business systems** and provides a product information backbone for companies and their extended enterprise.

PLM – the "results"

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its **conception**, through **design** and **manufacture**, to **service** and **disposal**. PLM **integrates** **people, data, processes** and **business systems** and provides a **product information backbone** for companies and their extended enterprise.

PLM – the practical "Backbone"

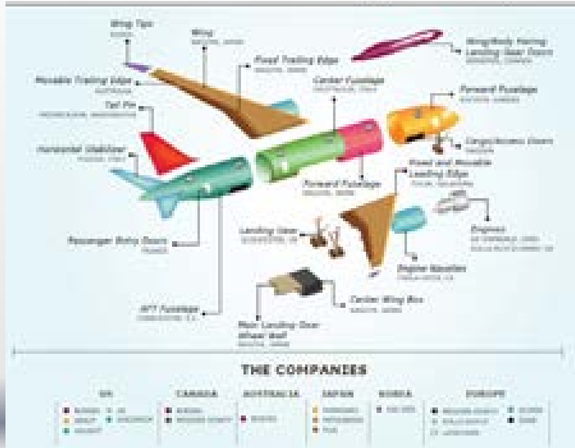
(A non "IT definition")

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its **conception**, through **design** and **manufacture**, to **service** and **disposal**. PLM integrates **people, data, processes** and **business systems** and provides a **higher product quality, cost reduction and expedited delivery time** for companies and their extended enterprise.

QA is integral part of PLM

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its **conception**, through **design** and **manufacture**, to **quality assurance**, to **service** and **disposal**. PLM **integrates** **people, data, processes** and **business systems** and provides a **higher product quality , cost reduction and expedited delivery time** for companies and their extended enterprise.

The 787 outsourcing challenge for QA



787 Dreamliner quality cost

"Boeing outsourced production around the world, but that caused **quality problems** and **delays** that sent the **$5 billion development costs soaring** - by some estimates to **more than $30 billion.**

The first plane was delivered **three years late, and those delays cost Boeing 160 orders**.

"There's no question **you lose credibility with your customers**," said Randy Tinseth, vice president of marketing for Boeing commercial airplanes.

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A real integral part of PLM?

product lifecycle management (**PLM**) is the process of managing the entire lifecycle of a product from its **conception**, through **design** and **manufacture**, to **quality assurance**, to **service** and **disposal**. PLM **integrates people, data, processes** and **business systems** and provides a **higher product quality , cost reduction and expedited delivery time** for companies and their extended enterprise.

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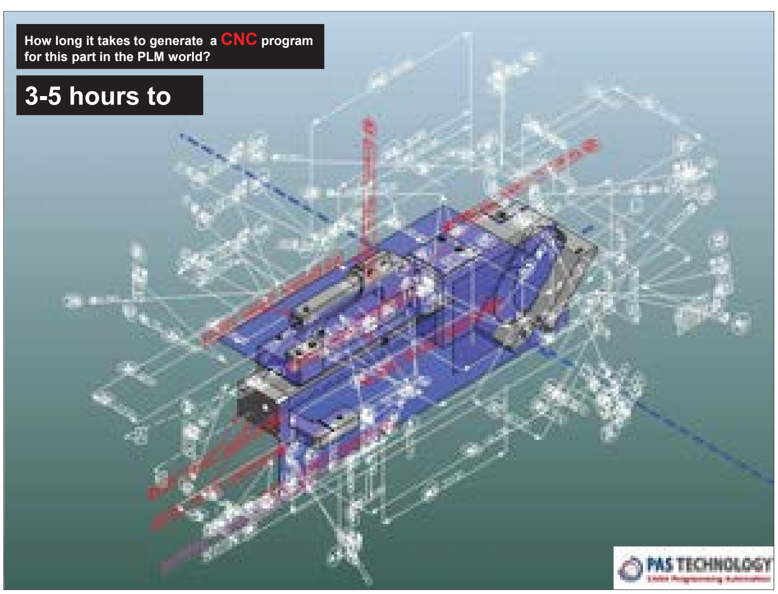
The inspection challenges

PAS TECHNOLOGY

How long it takes to generate a CNC program for this part in the PLM world?

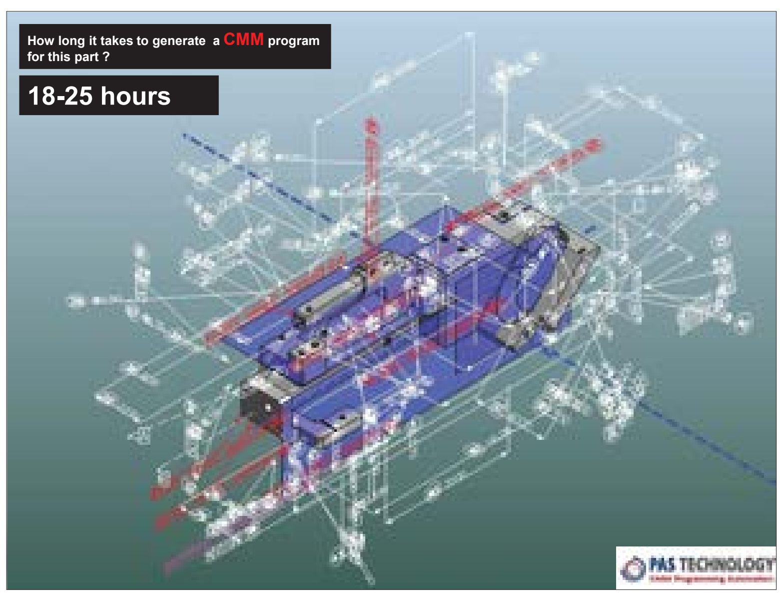
3-5 hours to



PAS TECHNOLOGY

How long it takes to generate a CMM program for this part ?

18-25 hours



PAS TECHNOLOGY

Why CMM program takes 5 time longer than CNC program? Because it is not part of PLM? Can it be?

Can this process "integrates"?

1. Inspection starts with **translated** model (IGES\STEP) with blue print
2. **Manual** ballooning on drawing or PDF
3. Model & Drawing requires **Interpretation** for inspection program
4. Inspected **feature's selection**
5. Annotations (dimensions, tolerance, datum, construction)
6. Parameters
7. **Manual** collision detection & prevention
8. **Engineering change control**
9. **Non standard** communication to CMM machines
10. **Manual reporting** (FAI) with **home grown excel** (for the most part)
11. **Trusted results**

Root cause samples

- **The process requires vertical (machine\software) CMM programming expert (non standardization)**
- **Programming and reporting is time consuming associated with manual labor intensive, interpretation and potential human errors (Delivery time, cost and quality)**
- **Lack of completeness and integrity due to "broken links" in the process (integrated)**
- **The industry in general is missing quality assurance data exchange standardization (translation, interpretation, delivery time, cost…)**

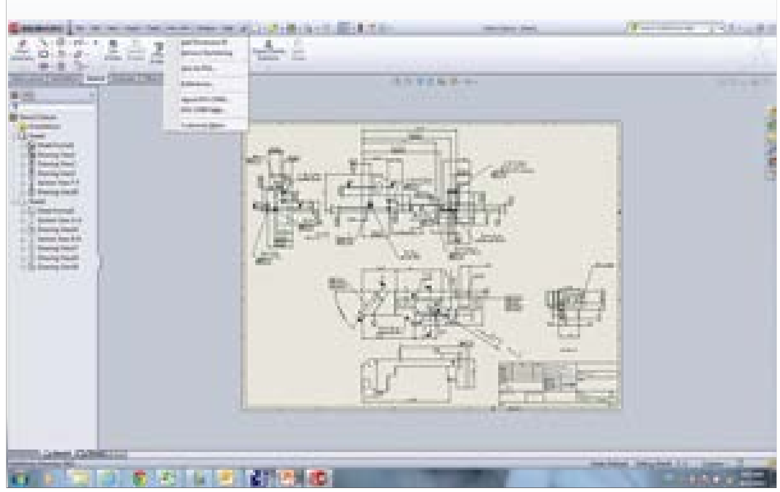
A quote from aerospace supplier

"As companies receive more and more **MBD** (model based definition) and the parts get physically bigger, the task of both inspecting the parts and controlling the manufacturing process grow by at least an order of magnitude. Programming the CMM in xxxxxxx no longer takes a **day, now it takes a week**, and then it takes **another week** to prove out and **understand the part results**. Then how do you guarantee that you have checked all the features when you programmed manually?"

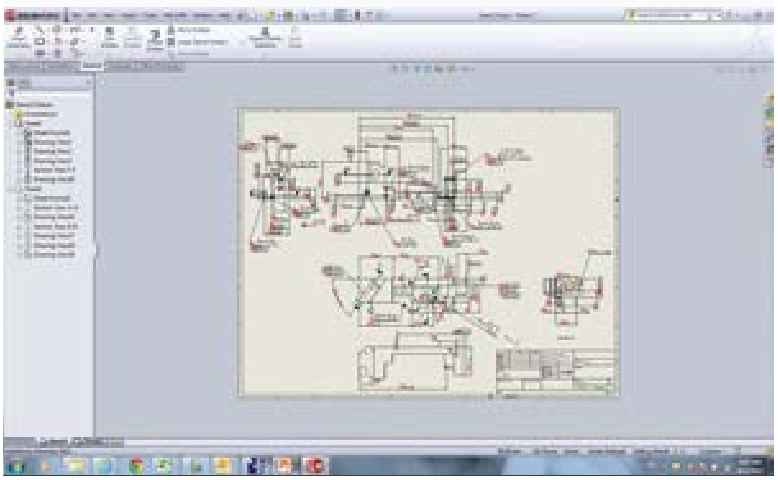
ILM – Inspection Lifecycle management as an integral part of PLM

From any native CAD model to trusted inspection results with no translation, no interpretation and no data entry once entered

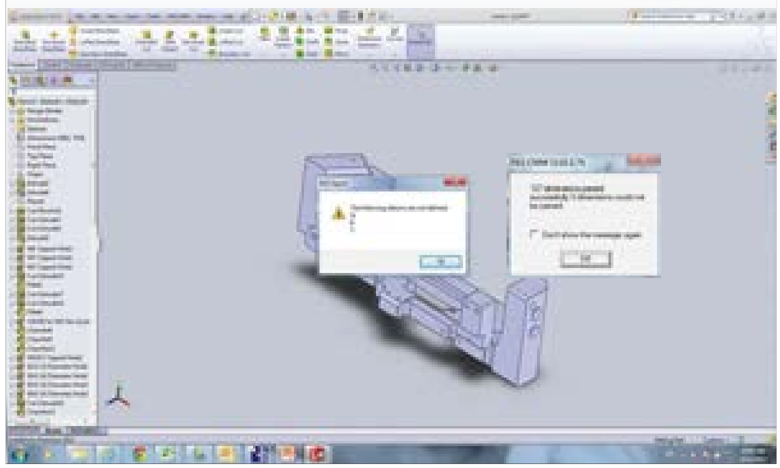
ILM process example – model & drawing stage



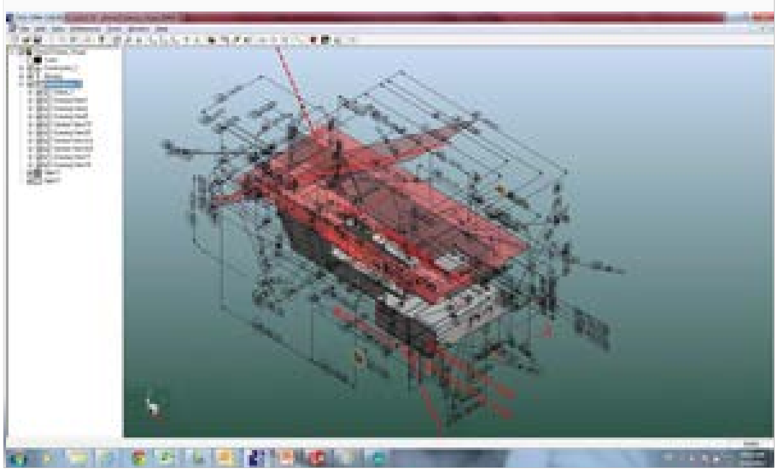
Automated ballooning and part inspection requirements analysis
(eliminating user inspection interpretation)



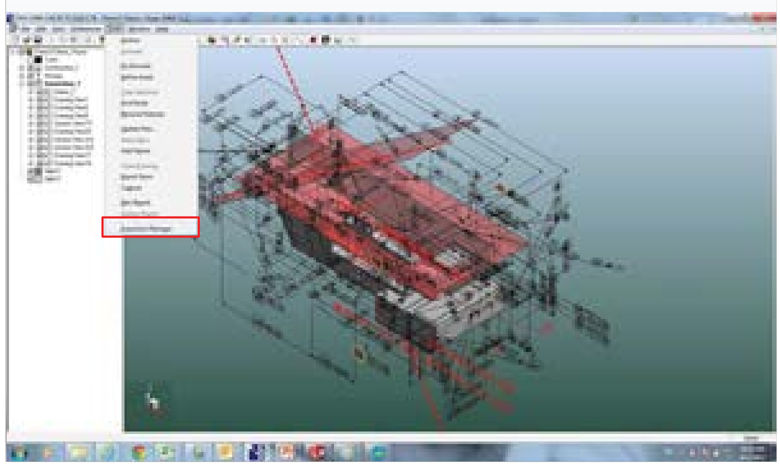
CAD model validation having all needed inspection information



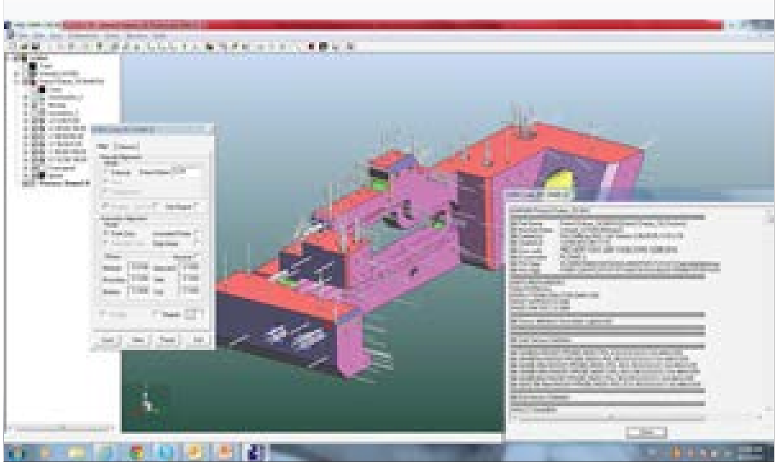
CAD model converted with all required inspection information including views and balloons



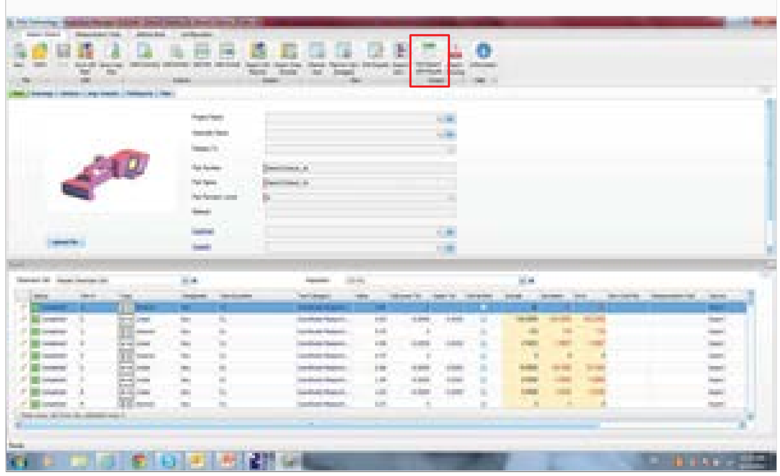
Creating inspection planning “package” electronically



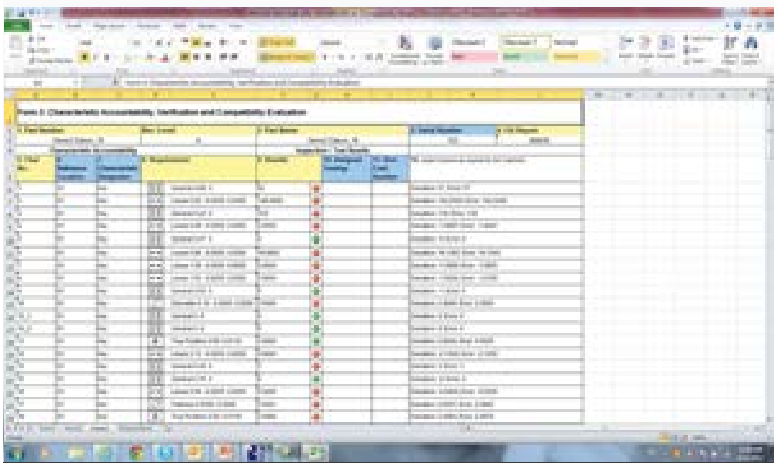
Part inspection completed in minutes as all required information converted from the CAD model



Inspection planning & results directly from the CAD model and from any CMM machine or other inspection tools.



First Article Inspection report in one click..



Inspection program & reporting (including FAI) in minutes rather than hours …or days with trusted inspection results

ILM can be an integral part of the PLM

Inspection lifecycle management (**ILM**) automates and manages the entire integrated quality assurance process from design to manufacturing to inspection to trusted inspection results.

Update on Key Model Based Engineering (MBE)-related Pursuits at NASA

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Presented at:
MBE Summit – NIST Gaithersburg, MD
December 12th, 2012

NASA Overview

Variety of Missions

Science

Explores the Earth, solar system and universe beyond; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society

- Earth: Weather, Carbon Cycle & Ecosystems, Water & Energy Cycles, Climate Variability & Change, Earth Surface & Interior, Atmospheric Composition
- Heliophysics: Heliosphere, magnetospheres, Space Environment
- Planets: Inner Solar System, Outer Solar System, Small Bodies
- Astrophysics: Stars, Galaxies, black holes, the big bang, dark energy, dark matter, planets around other suns

Human Exploration and Operations

Focuses on International Space Station operations and human exploration beyond low Earth orbit

- International Space Station
- Multi-Purpose Crewed Vehicle (Orion)
- Space Launch System
- 21st Century Ground Operations

Aeronautics

Pioneers and proves new flight technologies that improve our ability to explore and which have practical applications on Earth

- Green aviation
- Next Generation Air Transportation System (increasing safety and managing traffic congestion)

NASA's Culture & Organizational Challenges

- Composed of independent Centers
- Different missions but all include engineering of some kind
  Interactions between centers tend to be project-specific
- Extensive dependence on prime contractors
- Every project negotiates own contracts
- Long product development and operational life cycles
- Difficult to coordinate change due to timing to converge on any common approach(e.g., 3D CAD did not exist for Voyager 37 years ago)

NASA Activities Related to MBE

Internal Activities Related to MBE

- Developmental Engineering
- Systems Modeling & Simulation
- Verification & Validation
- Vehicle Systems Integration
- Flight Operations
- Some Prototyping and Test Article production
- Post Event Analysis and Review (e.g., CAIB, In Flight Anomalies)

External Activities Related to MBE

- Concept Development & Proposal Reviews
- Prime Contractor Interfaces
- Insight & Oversight (e.g., for fully-outsourced development and production)
- Systems Integrations (e.g., science payload on ISS)
- Vehicle Acceptance (e.g., SRBs arrive at KSC)

NASA's Drivers for MBE

What Drives NASA's MBE work?

- Nature of work is dominated by **Developmental Engineering**
- Very **low volumes** of complex products
- Conceptual Engineering
- Systems Engineering
- Systems Integration

- **Past Experience**
  - NASA has pioneered several specialized engineering technology advances (e.g., FEA)
  - Columbia Accident Investigation Board Report specifically pointed to product data issues
  - New insights into the flow of data within Engineering and downstream activities (e.g., from Ares)
  - Discipline-focused Working Groups converging on similar issues (e.g., MBSE, Modeling & Simulation, CAD Interoperability, PDLM)

What Does NOT Drive NASA's MBE Work

- Manufacturing or Supply Chain Coordination (due to low rates)
- Unit cost reduction (typically make ≤ 3 of a design)
- Lifecycle cost optimization due to product design (special purpose needs and operational environment are more significant)
- Reuse of design data for new products

NASA MBE Activities

Associated with Two Initiatives

- NASA Integrated Model-centric Architecture (NIMA)
- Product Data Management & Interchange

Areas We Are Looking At

- Cross-mapping of model maturity states to support pre-release exchange
- Parsing the Modeling & Simulation Territory
- Moving away from Document-Centric engineering practice

Areas Needing More Attention

- Records Retention and Archiving
- Acquisition and Contracting Practices
- Configuration Management for Complex Hybrid Products

NASA Integrated Model-centric Architecture

Goals:

- Increase *affordability* through use of a model-centric architecture
- Achieve *interoperability* within and among programs/projects, centers and external partners through use of a model-centric architecture
- Inform/train invigorate *workforce* on model-centric architecture
- Improve product *quality* and success through use of a model-centric architecture

- ***Benchmarking***-- The following companies were benchmarked :
  - ATK – Brigham City, Utah
  - Whirlpool Corporation – Benton Harbor, Michigan
  - Ford Motor Company – Detroit, Michigan
  - Lockheed Martin Joint Strike Fighter – Fort Worth, Texas
  - Lockheed Martin –Space Systems Company – Littleton, Colorado
  - Pratt &Whitney Rocketdyne – Canoga Park, California
  - **And two internal**
    - JPL
    - JSC Engineering

NASA Integrated Model-centric Architecture (continued)

Benchmarking:
Typical capabilities that were explored in each of these areas

CoP	Capabilities/topics explored	
MBSE	Motivations/Business Case MBSE Vision Infusion Strategy & lessons learned Implementation System Model and Linkages Model Data Exchange	Tools and Standards Methodology/framework Metrics
PDLM	Managing the product configuration Criticality of PDLM to your business Use of models for 3D model visualization	Integration with manufacturing systems Ensuring appropriate revision of data
CAD	Electrical and mechanical design tools Enabling data exchange Use of 2D and 3D	Tool selection criteria Return on investment for tools How analysis and simulations can be improved using CAD
M&S	Applications used Model reuse Simulation environments	Linking models together Visualization
General	Organization layout Definition of MBSE, PDLM, CAD, M&S Overall process use of standards	How funded Tool selection Benefits Training

NASA Integrated Model-centric Architecture (continued)

Selected Quotes from companies:

- "We did a full study alongside an existing study and found it reduced development time by 2/3. It increased reliability without changing the costing table. Trades were made much easier by having data available. It gives a better roadmap to program/project managers for how to cost. We are seeing positive trends"
- "You can't afford to do business like you did before. You can't afford NOT to leverage this technology"
- "Have seen a lot of positive benefits, when there were failures it was due to trying to do too much at one time"
- "MBE must be used early and often as possible to see the benefits"
- "Leadership must make a solid commitment"
- "MBE has many keys to breaking the spiral of cost and schedule overruns"

NASA Integrated Model-centric Architecture (cont'd)

Major On-going NIMA Activities

- Developing Concepts of Operations
- Assembling information on various pilots across agency
- Assessing Workforce Awareness & Training Needs
- Pre-release product data state cross-mapping (More later)

Product Data Management & Interchange

Proliferation of silos and differential learning but some notable progress

- **Ten+ PLM systems at NASA**
  - Tool and architecture selected before 3D CAD and prior to large programs like Constellation
  - NASA cannot dictate what primes use
- **Inconsistent experience with 3D CAD**
  - Detail design work often outsourced or handled by prime
  - Projects have a lot of authority to choose their engineering tools
- **Project and Systems engineering policies inconsistent on topic of models**
  - For example, may substitute "model" wherever they had "drawing"
  - Practice is driven by Center-level policies, procedures, handbooks

Improving Product Data handling is a multi-party, multi-faceted effort

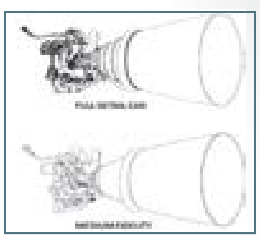
Agency-level Product Data and Life cycle Management (PDLM) Policy (NPR 7120.9)
- Comes from recognition of major risk on Constellation
- Basically requires a PDLM plan for significant space flight projects
- So far, only applied at beginning of projects (e.g., few PDLM plan updates as yet)

PDLM NPR is project-focused
- Does NOT expect or encourage projects to provide own separate model management tools
- Does not replace Center-standards
- PDLM Handbook approval expected <30 days
- Needs guidance for acquisition, internal flows of engineering info, etc.

New policy impact can be hard to see
- PLM tools "owned" by individual Centers
- Ongoing disconnect between CIO and Center & Project Engineering on engineering IT
- Funding by project (vs. organization) diffuses leverage to make organization-centric changes

Improving Product Data handling is a multi-party, multi-faceted effort (cont'd)

Variable progress seen at different scales
- **Building new practices for pre-release CAD data exchange**
  - MSFC Handbook 2644, "Design Product Package for Launch Vehicle Integration "
  - Bringing envelope models from multiple design sources together to support vehicle integration and vehicle
  - Builds on a pending CAD Interoperability Standard derived from Ares experiences



(Engine Outer Mold Line Models)

MBSE adoption can be found at every Center on different scales/life cycle stages, e.g.,
Example -- JPL Collaborative Engineering facility using SE models (concept/preliminary design)

Capturing insights from recent projects like Constellation's /Ares (next chart)
#1 corresponds to new MSFC Handbook
Interestingly #2 reflects a bi-directional flow to/from contractor
Only one (#7) met by NIST 2011 TDP

Improving Product Data handling is a multi-party, multi-faceted effort (cont'd)

Getting Specific: CAD Interoperability Insights for Project Data Acquisition & Exchange

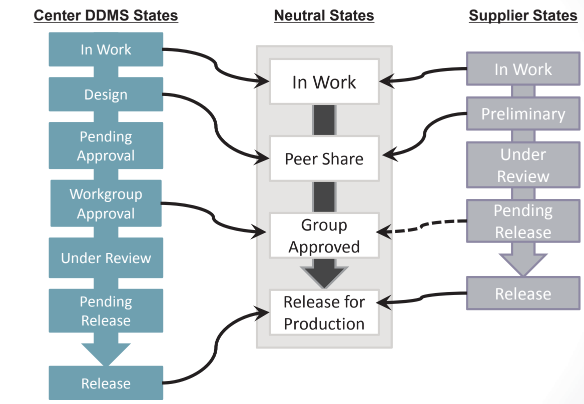
If we want to:	Likely we would need CAD specified like this:
1. Do design integrations	Specific pre-release models to defined (high) accuracy based on negotiated agreement between provider and user (e.g., per NASA-STD-0007 or MFSC HDBK 2644)
2. Sub-contract part of design work	To send contractor skeleton files, start parts, approved parts lists….AND receive back from them design files, component models, and other elements of product definition package
3. Take over design change authority	Full design history and 3D CAD models for a given vehicle block, including skeletons, standard parts, start parts, drawings, configuration settings, model checking criteria
4. Conduct design review	3D "viewable" of released models or external alternative representations that support annotations
5. Do derivative designs such as GSE	Pre-release CAD models from source at defined maturity level treated as "released" by users within their own environment with associated metadata
6. Do modeling and simulations	Pre-release alternative representations with full definition of items significant for modeling and simulation and with settings to support conversion to VRML, etc.
7. Re-bid production	Released CAD models, drawings, material specs, manufacturing processes, installation models, etc.
8. Do physical integration & verification (e.g., at VAB)	Released alternative representations or source CAD with appropriate alternative representations substitutions with full definition of items at integration point (but lacking internal detail)
9. Acceptance Data Package for physical delivery	CAD need based on defining requirements–who/what/when/how models will be used–to assure that they are right lifecycle/maturity state, format, and contain needed content

Areas we are looking at:

Cross-mapping of model maturity states to support pre-release exchange (moving under NIMA)

- Driven by need to exchange models during development
- Many reasons for differences in maturity states
- Seeking PLM tool independence (interoperability – open standards based)
- Traceability and understanding of changes
- Significant need for engineering analyzes and oversight
- For confidence in Decisions and Reviews

Interoperability for Engineering Release via State-Compatibility Mapping (Notional Only)



Areas needing more attention

Records Retention and Archiving

- NASA <u>simultaneously</u> (currently 90 active science programs) producing records in formats originating across decades of development and operation
  - No universal format or storage medium covering Voyager, Shuttle, and James Webb telescope

Acquisition & Contracting Practices

- Contract language often inappropriately reused
  - Knowledge gap between technical data users and PM/contracts people
    - Few understand the consequences of defaulting to "least common denominator" formats (e.g. PDF, native CAD, etc.)
    - Can NO LONGER rely on referencing *<u>exisiting</u>* data management and CM policies
- Much data that will be exchanged is not anticipated when contract written
  - Large cost and time impacts associated with contract changes
  - Technology to be used for some engineering work undetermined or may not even exist when contract signed

Areas needing more attention (Cont'd)

Configuration Management for Complex Hybrid (HW/SW) Products

- Moving beyond CM based on document or file-centric approaches
  - Does not reflect advances in technology of product definition
  - Current focus on "end-of-pipe" design product ignoring huge volumes of engineering data
  - Multiple design and verification cycles

Some Observations and Conclusions

Observation: Being complex project-centric with extremely low volumes matters

- NASA's project-orientation is an independent source of diversity
- Many highly technical domains producing and keeping large data volumes
- If you are making <3 of something, you can bend some rules

Conclusion: NASA driven more by engineering developmental phases than hand-off to production

Observation: Everybody's a data supplier and a data customer

- Multiple disciplines involved who are accustomed to pursuing their own technology solutions
- Exchange of engineering models is increasingly a driver for project timing and cost

Conclusion: Engineering and IS need to collaborate to build adaptable "data supply chains"

Observation: NASA's very long development and operational cycles shift incentives for action

Conclusion: This is an "multifinal" case* with more than one acceptable solution

** Multifinal is defined as the potential for similar initiating factors to result in diverse outcomes.*

Some Imperatives for Realizing Model-Based Products

Richard Neal

Integrated Manufacturing Technology Initiative

<u>SOME</u> Imperatives for Realizing Model-Based Products

- Systems compatible and Resilient
- Totally Connected and Integrated across the product lifecycle
- Optimized early with clear definition of costs and risks
- Model-based and knowledge rich
- Collaborative and Secure
- Drives downstream applications and enables and delivers a complete Technical Data Package

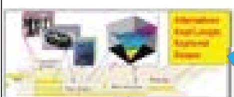
Systems Engineering and Design and Manufacturing – Just Personal Observations

- Systems engineering focuses on how products should be designed and managed across their lifecycle. Some discriminators include:
  - Broader view of the acquisition process
  - Driving the emphasis on lifecycle issues, logistics
  - Deals with the complexities of systems – especially large systems
  - Focused on risk, uncertainty, etc
- A systems view enables optimization across domains, disciplines, subsystems, perspectives . . .
- Obviously, "design and manufacturing" is changing dramatically!

"Boeing has Learned that Every Design or Manufacturing Engineer, No Matter What the Discipline, Must Be a Systems Engineer"

Engineered Resilient Systems Key Technical Areas

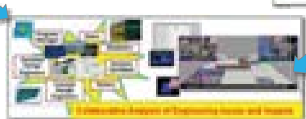
Systems Representation and Modeling
- Physical, logical structure, behavior, interactions, interoperability…



Characterizing Changing Operational Contexts
- Deep understanding of warfighter needs, impacts of alternative designs

Cross-Domain Coupling
- Model interchange & composition across scales, disciplines

Data-driven Tradespace Exploration and Analysis
- Multi-dimensional generation/evaluation of alternative designs



Collaborative Design and Decision Support
- Enabling well-informed, low-overhead discussion, analysis, and assessment among engineers and decision-makers

From Presentation by Phil Zimmerman

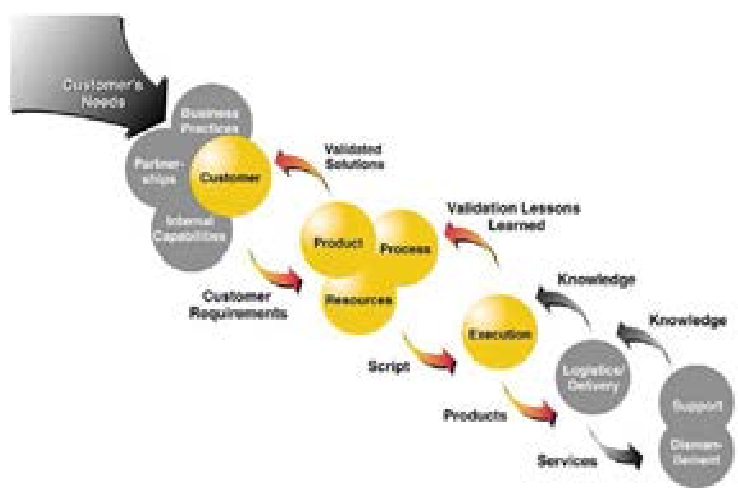
Totally Connected and Integrated across the product lifecycle

Totally Connected and Integrated across the product lifecycle

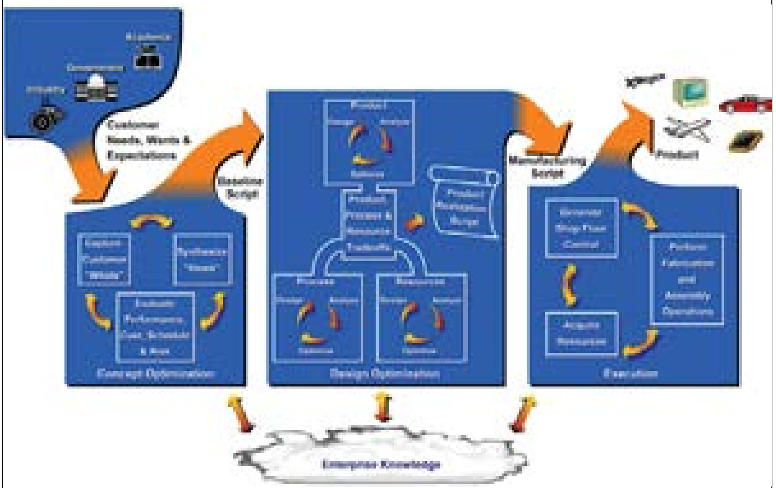
- There is nothing new about "moving manufacturing forward"
- <u>We</u> have sought for two decades to drive a concept of a totally integrated view of the design and manufacturing lifecycle
- These concepts might provide great historical context for moving toward Engineered Resilient Systems

A Look at Attempts to Communicate this Basic Concept Might be Fun – and Instructive?

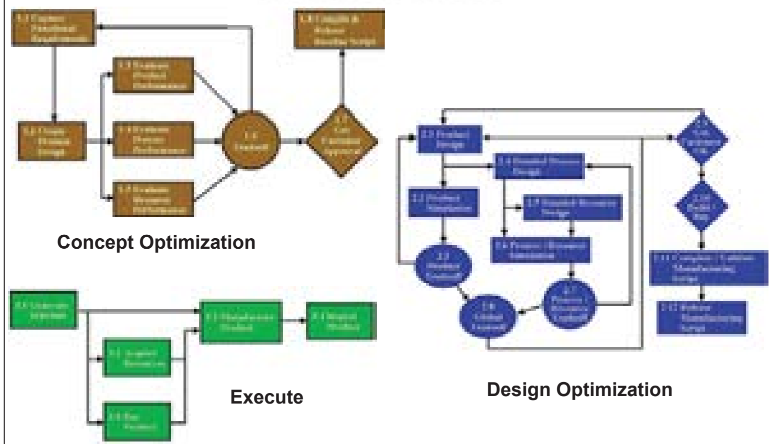
The Enterprise



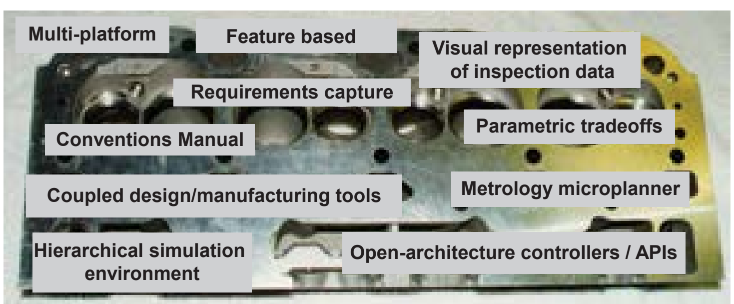
The TEAM Product Realization model

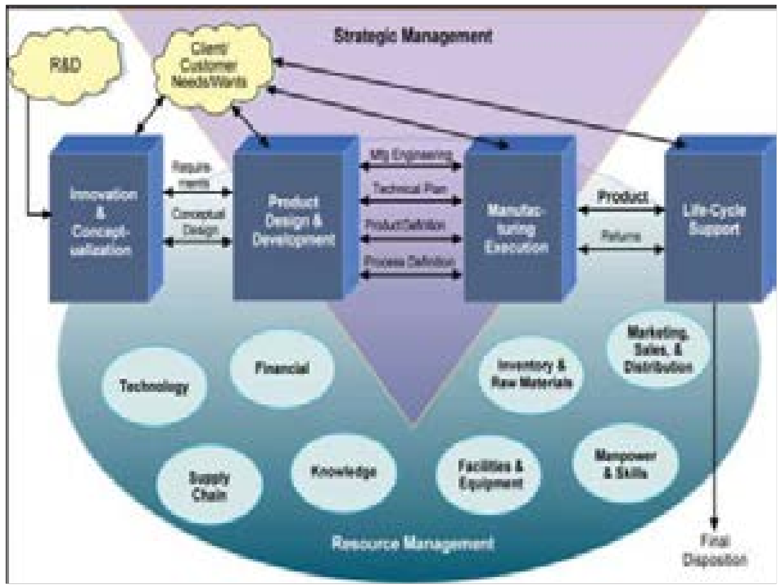


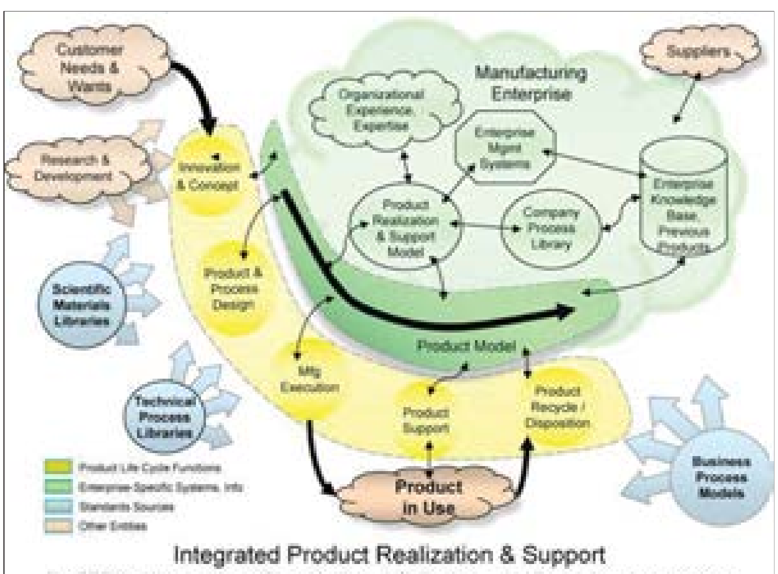
Workflow models



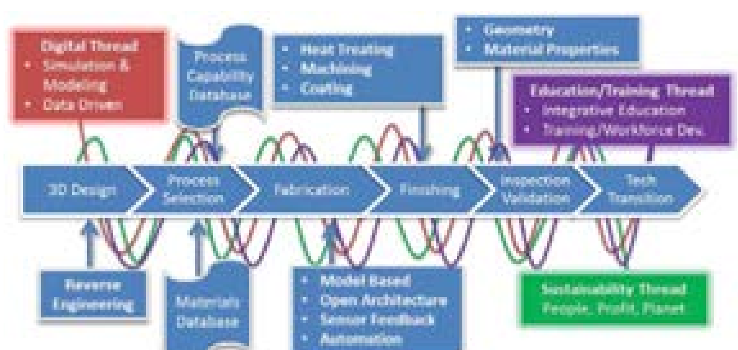
The Integrated Material Removal Demonstration Emphasized Internet Based Interoperability--







Characteristics of the NAMII Integrated Technology Plan



Enough: What's the Point?

- The model-based enterprise must be an implementation of a totally connected, integrated system of much more than models
- Everyone is on to the same big ideas, and the emerging strategies are similar
  - NNSA – PRIDE
  - ManTech – Advanced Manufacturing Enterprise
  - Systems Engineering – Engineered Resilient Systems . . .

Concept to Manufacturing and Lifecycle Support is a System and Must be Totally Connected and Integrated

Optimized early with clear definition of costs and risks

Optimized early with clear definition of costs and risks

- Everyone knows the horrors of cost escalation and time extension
- Key reasons:
  - Deployment of immature technologies
  - Failure to understand cost and risk early
- The process starts with what is needed (in DoD terms) and what will sell (in commercial terms)
  - Understand the "heart and soul of the user"
  - Understand what could be
  - Understand what is required
  - Break the string of minor variants

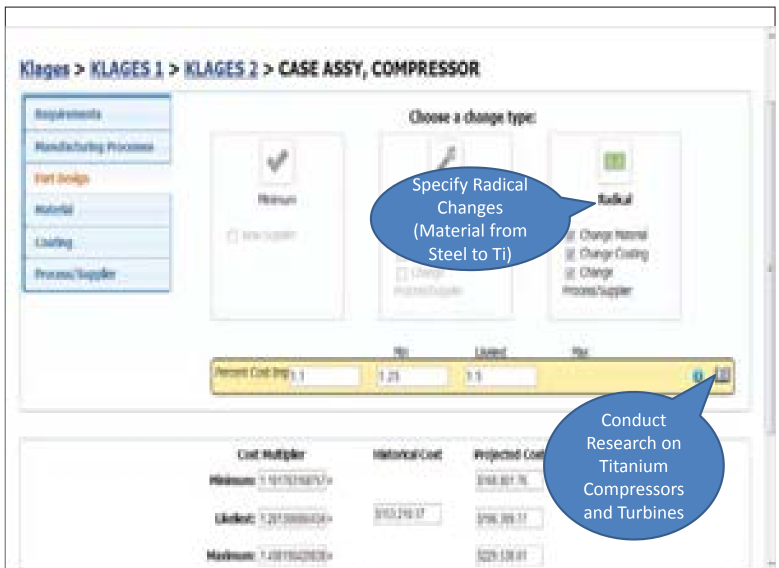
A Rich Assessment and Optimization Environment Enables the Unbounded Exploration of the Possible to Find the Best Total Value Solutions

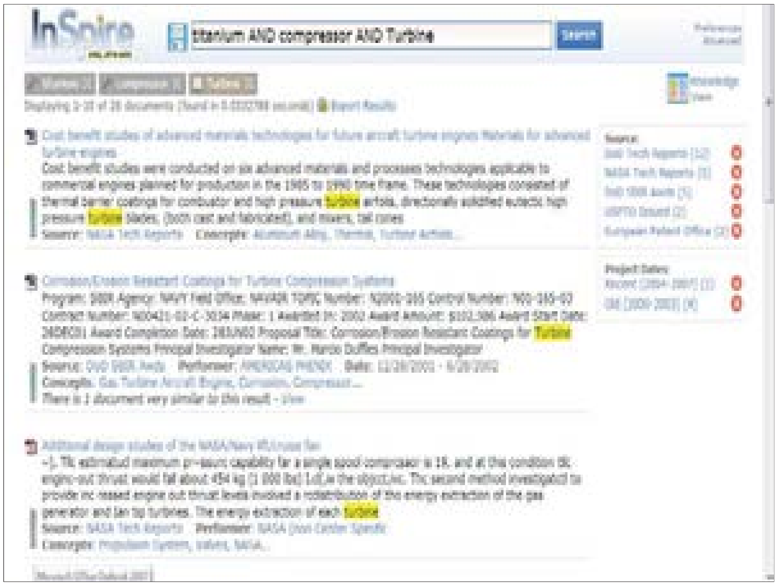
An Example of an Emerging Methodology

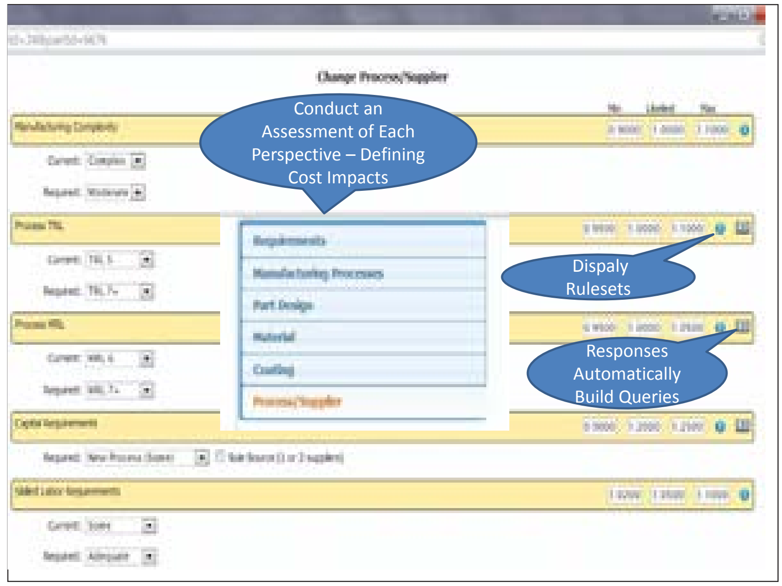
The pilot system:

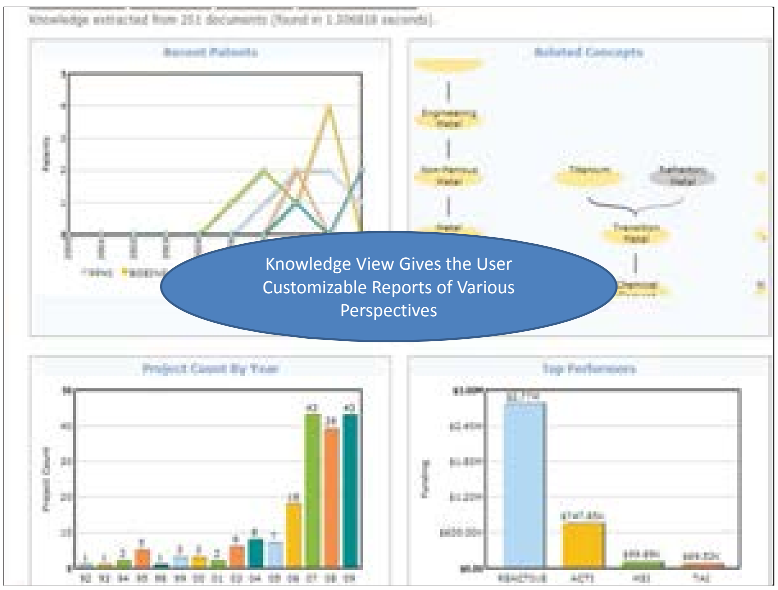
- Accepts all inputs
  - Requirements
  - Historical costs
  - Lessons learned
  - Rule sets . . .
- Assesses the risk of cost escalation in a hierarchical structure
- Leads the user through a cost optimization and risk mitigation process

In Many Cases, Detailed Cost Analysis is not Performed Until Detailed Designs are Delivered. The Cost and Risk Assessment and Trades Should be Pushed to the Front!









The Evaluation Process

- The exclamation icon shows rule sets; the book icon launches intelligent search
- Every perspective is evaluated and cost escalators and de-escalators are assigned
- The costs are rolled up and risks are reassessed with each evaluation
- A hierarchical control structure enables collaboration and control of systems, subsystems, and components

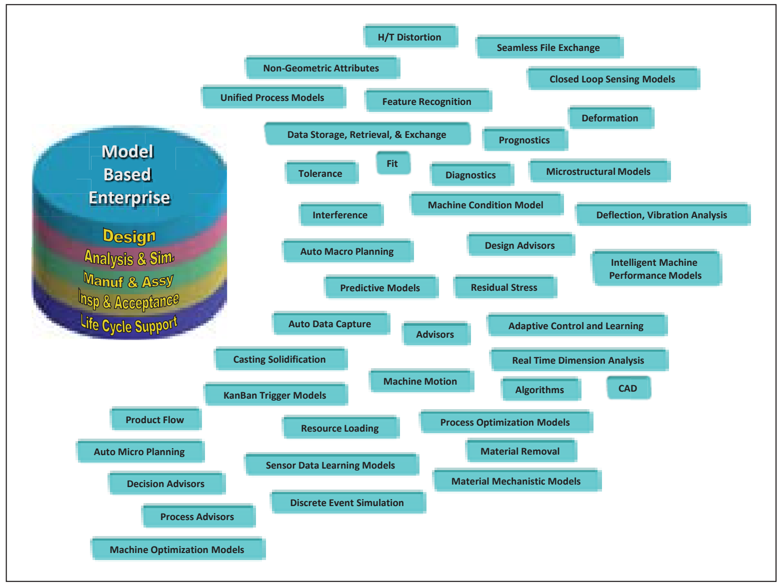
An Evaluation and Optimization of Sub-systems and Components that Pose a Significant Risk of Cost Escalation with Optimization and Risk Mitigation - Lower Cost and Assured Affordability

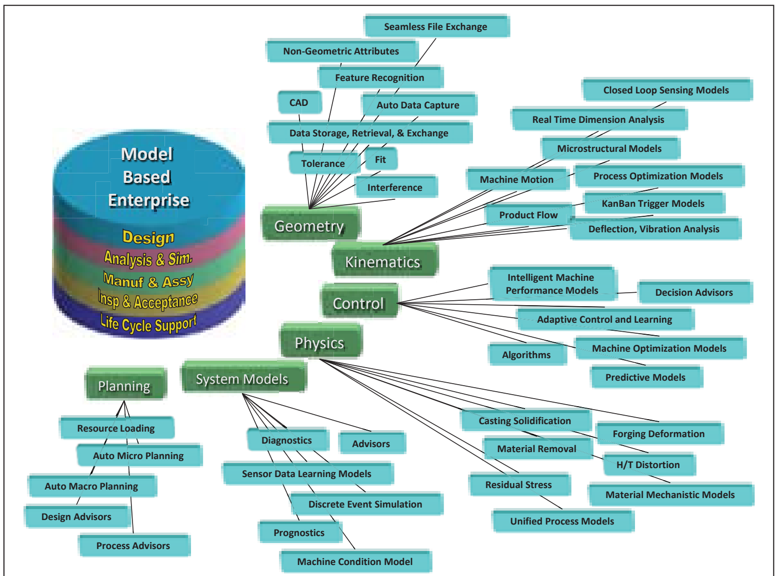
Model-based and knowledge Rich

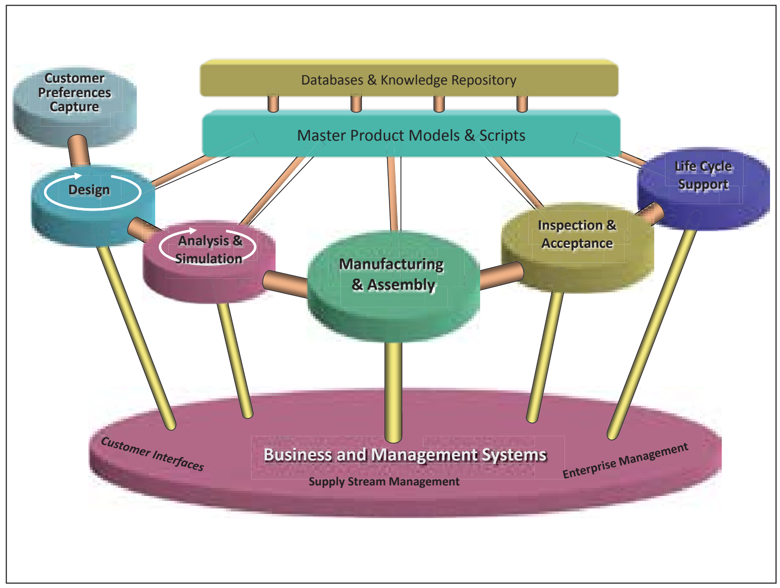
A Models Perspective

- Resilient models are elastic and not plastic
- The domain is too large to produce and manage models for every function and application
- Models should capture science by class of function and parameters within allowables
- Models can then be adapted for specific applications and attributes

Models Become Much More Efficient and Effective When Coupled With Knowledge







Knowledge Applications

The most ignored opportunity for dramatic improvement in producibility and affordability, and a key to resiliency, is the capture of knowledge for automated best practice

- For most processes, 80+ % of the challenges can be addressed in knowledge systems, making time for custom innovation
- Knowledge systems can be flexible and can learn, negating the strongest argument – but science does not change
- When models and analytical tools are coupled with knowledge, dramatic results are realized

RIGS - An Old Story – Still New

- KD Thompson was retiring – the sole provider of routine rolling plans for 25 years
- Six weeks were spent capturing his “knowledge”
- When reviewed with the metallurgists, “Eurekas” abounded
- Six rulesets resulted and were captured
- The system was unused, until the “impossible challenge” was presented
- The system delivered 17 compliant plans – prioritized against metrics
- Result: One of the components of an expert advisor toolkit that includes forming die design, CMM programming, process planning, etc.

Cost Savings, Resiliency, Capability Assurance, Time Compression . . .

Collaborative and Secure

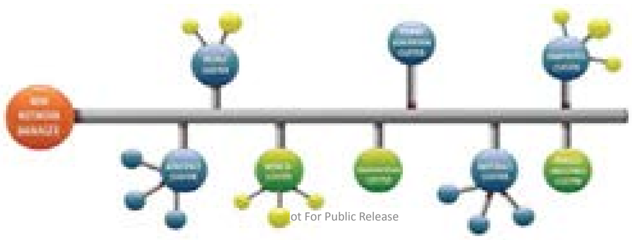
Today's Realities

- Secure information comes in many views from totally open to highly classified. Resiliency demands ready and secure access to exactly what is needed
- Individual projects, programs, and organizations each have their own IT strategies
- Unifying information access, project and program management in a secure environment will pay great dividends

We Need a Comprehensive Infrastructure for Managing the Delivery of Critical Solutions

Manufacturing Innovation Network (MIN): Cluster Manufacturing And Hub Enterprise Concepts Enable Acquisition Innovation.

- MIN is a member-driven, self-forming network and must be administered federally to maintain system security and integrity.
- MIN is the "Enabling Technology" that maximizes collaboration and innovation by:
  - eliminating "government and industry silos"
  - establishing the highest level of information security and
  - providing comprehensive connectivity among MIN partners.

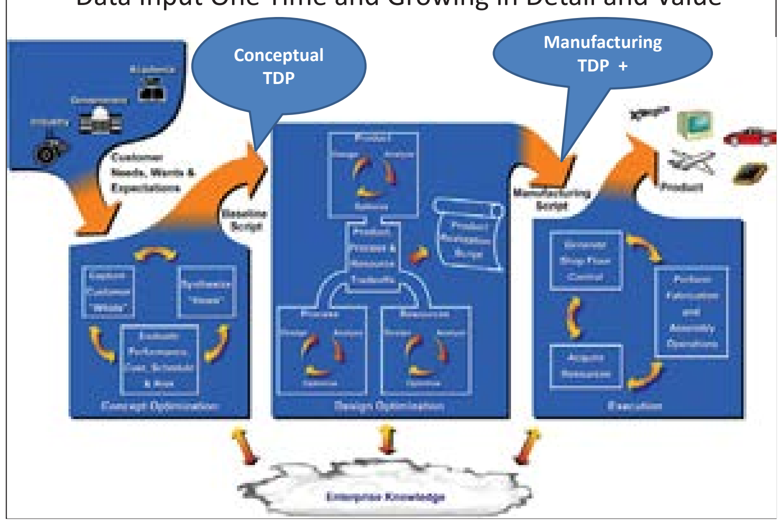


MIN Pilot Features

- Provides a platform for acquisition management
- Provides access to needed systems
- Assures management of all levels of information security
- Places the program manager or designee in the control position – with broad visibility
- Enables negotiation and agreement concerning access
- Leverages a national asset in "Your Cloud"
- Manages supply networks for best results

Drives downstream applications and enables and delivers a complete Technical Data Package

Data Input One Time and Growing in Detail and Value



One-time Data Entry and Growing to Support What is Needed

- Begins with many possibilities/requirements
- Evaluation is rapid for fast failure, easy recovery, and automated/augmented optimization
- Concepts convey elementary design data which is taken to appropriate fidelity (goes away?)
- Design data supports all planning functions and spawns operational and sustainment models
- The resulting model set is so complete that it becomes the product and process controller for assured product delivery

As Conceived, as Designed, as Planned, as Built, as Used, as Supported in One Data and Model Set

Conclusion

- There is strong consensus about the goals and the strategies
- Model-based product delivery is mature to the point of getting it done!
- Needed tools and methods are maturing that enable the realization of the vision
- It is time for unified programs that deliver the implementation of the vision

The MBE/TDP DEDMWG Activity Provides A Great Success Model

Model standards interoperability across domains, the life cycle, and the supply chain

Charlie Stirk
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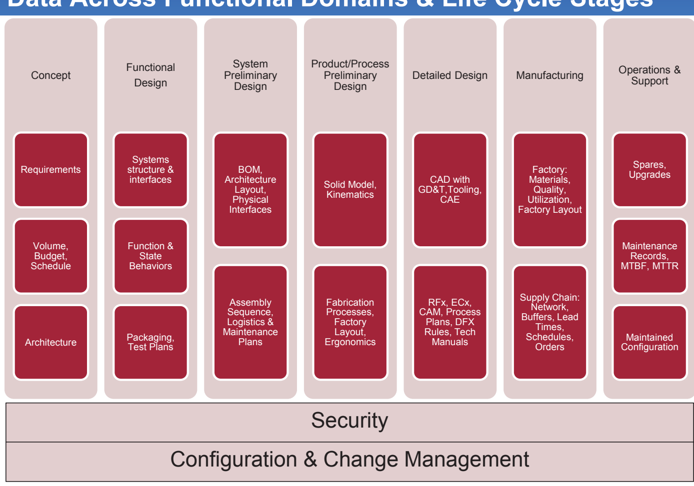
Dec. 13, 2012

My perspective …

- Cost models need to interoperate with other models
  - Requirements, Arch., Project, CAD, Assembly, Mfg., O&S
- Standards Involvement
  - PDES Manufacturing & Systems Engineering Teams
  - INCOSE MBSE, Tool Integration and Interoperability
  - OMG Model Interchange Working Group
  - CAX Implementor Forum
  - PLCS Implementor Forum
  - AIA/ASD Long Term Archiving and Retrieval (LOTAR)
    - Product Data Management & Metadata Teams
  - AIA/ASD Integrated Logistics Support (ILS S-series)
    - Data Modeling and Exchange Working Group
- Use of other technologies
  - OAGIS, Acrobat/3D PDF, COLLADA, CAD/PLM API's

Data Across Functional Domains & Life Cycle Stages



STEP Modular Architecture (STEPmod)

- Modular Application Protocol (AP) Benefits
  - STEP Module and Resource Library (HTML on CD) for CHF 352
    - Faster revision process (months rather than years)
  - Interoperability of implementations through module & code reuse
    - requirements, assembly structure, geometry, PMI etc.
- Two implementation levels
  - ARM domain-specific entities map to MIM entities from integrated resources
- Modular STEP AP Domains
  - AP209 CAE (FEA and CFD)
  - AP210 EDA/MCAD (electrical and mechanical assemblies)
  - AP233 Systems Engineering
  - AP239 Product Life Cycle Support (PLCS)
  - AP242 Mechanical CAD (parts & assemblies)

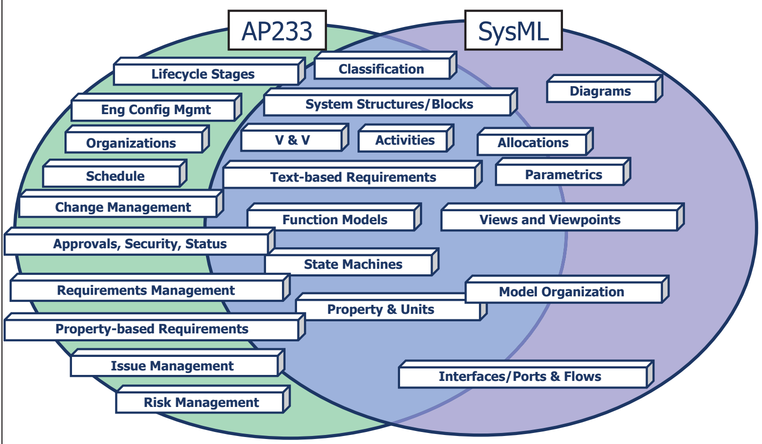
Program and Project Management

- Earned Value Management (EVM)
  - UNCEFACT based XML Schemas for Cost and Schedule
  - Cost classification by Work Breakdown Structure
    - MIL-STD-881 for systems (but hybrid breakdown)
    - Operations & Support WBS (functional breakdown)
  - DoD requiring on all large programs for EVM baseline and reporting to Central Repository
- NATO Guidance on Life Cycle Costing (ALCCP-1)
  - Recommends use of PLCS for data collection
  - Recommends standard Cost Breakdown Structure
  - Recommends standard activity and resource classification
- Collaborative Project Management (CPM)
  - Usage Guide, Data Exchange Model, Implementation Guide
  - By ProSTEP iViP with German auto industry
  - XML schemas and WSDL transport

Systems Engineering Model Standards

- SysML = Systems Modeling Language
  - Diagram language based on UML/OMG MOF
  - XMI = XML Model Interchange format
    - Written specification for OMG MOF (interpreted!)
    - Canonical XMI is restricted specification (NIST Validator)
    - OMG MIWG testing conformance, but not interchange yet
    - Need UID for diagram/data management
    - Without diagram exchange, limited to libraries or manual model re-building
  - Partial mapping with AP233 needs completion
- ReqIF = Requirements Interchange Format
  - XML schema for spec hierarchy, data types, attributes
  - Several versions in use
  - Vendor implementations not interoperable
  - ProSTEP iViP setting up an implementers forum
  - Early version mapping with AP233 needs updating/validation

SysML/AP233 Data Overlaps



Model Transformation Technologies

- XSLT (Extensible Stylesheet Language Transformations)
  - Between XML documents, HTML, PDF, relational databases, …
  - Many proprietary and open source implementations
  - E.g. STEPmod publishing system for STEP AP's
- EXPRESS-X (ISO 10303-14)
  - Data between EXPRESS schemas
  - NIST Expresso open source and commercial tools
  - E.g. implement STEP ARM to MIM/AIM mapping
- Meta Object Facility (OMG MOF)
  - Typically between UML derived languages and models
  - Ecore variant in Eclipse Modeling Framework commonly used
  - Transformation languages: QVT, ATL, VIATRA
  - E.g. ReqIF to SysML Requirements

Use of AP233/239 in Systems Engineering

- Early version of AP233 used for
  - Data Migration between Slate and TeamCenter SE
  - Mapping of CADM 1.5 format for DoDAF
- AP233 and AP239 Convergence
  - AP239ed2 contains all but 233's Issue and Behavior Models (State Machines and Enhanced Functional Flow Block Diagrams)
    - Roll them into modules or reference data
- AP239 PLCS used to manage mapped objects
  - PLCS supports relationships & configuration management
    - Like earlier work with CADM, IFC, SysML
    - Add ReqIF, UPDM, EVM, CPM, etc.
  - PLCS provides links to other domains (PDM, LSA, provisioning, scheduled maintenance, tech pubs, field data ..

PDES Systems Engineering Projects

- Requirements Traceability
  - Decomposition from Capabilities to Specifications
  - Across supply chain
  - Across tools (DOORS, ReqIF, SysML, etc.)
  - To verification & validation artifacts
  - Engineering change processes
- Systems Model Interoperability
  - Architecture, Behavior, …
  - Across lifecycle (Architecture, Systems, Design, Test, etc.)
  - Across languages (UPDM, SysML, UML, AADL, domain specific, …)
- Sharing info with ProSTEP iViP Smart Systems Eng.
  - Initial focus on Modelica Functional Mockup Interface (FMI)
  - Have advantages over Matlab/Simulink S-Functions

Convergence of AP203 (Aero) and AP214 (Auto)

- Create single superset standard for MCAD
  - 203 x 214 = 242 and upwardly compatible
  - Modularization for interoperability across domains
  - Already harmonized for geometry (translators handle both)
- 214 adds the following capabilities
  - Manufacturing process planning
    - Relate plans, operations, tools, raw/in-process/finished, projects, other activities, etc.
  - Kinematics
  - Machining Features
  - OMG PLM Services (web services API) for PDM and Engineering Change
- Enable association with 203 unique capabilities
  - Catalog, Composites, Construction History, Requirements

New Functionality for AP242ed1

- Business Object Model (BOM)
  - AP214 ARM was higher level than STEPmod ARMs
  - Upward compatibility for AP214 ARM based implementations
  - Harmonization ongoing with AP239 for PDM
  - Mapping from BOM to ARM
    - Enables higher level API
    - Composites then PDM and other areas
    - Eventually kinematics and mfg. process for visualization
- Shape Data Quality
- Access Rights Management
- Expanded Kinematics Simulation
- Improved PMI
- External Element Reference (eg. for Assembly PMI)
- Tessellated Geometry

- EXPRESS schemas and draft recommended practices available for testing

Proposed Functionality for AP 242ed2

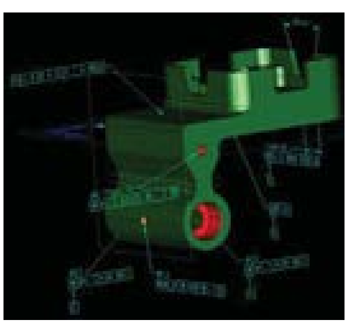
- 3D parametric / geometric constraints design
- 3D kinematics assembly
- 3D GD&T at assembly level
- Sustainability information
- Software / mechatronics
- 3D electrical harness
- 3D piping

AP242 PMI Subgroup work deferred for lack of funding

- Mapping of screw threads standards to AIC522/AM machining_feature
- Welding standards (ISO 2553, AWS A2.4)
- PMI for ISO assembly documentation, assembly technology, assembly joint
- Support of adhesive standards (ASTM D7447)
- ISO 1101 FDAM1 - Tolerances of form, orientation, location and run-out
- Surface texture (ISO 1306, etc. and ASME B46.1)
- Other items that had been categories as out of scope for PMI-1 e.g. spot-face
- Update for new editions of ASME Y14.41 and ISO 16792

CAx-Implementor Forum

- Joint testing effort of PDES Inc. & ProSTEP iViP
- Participants: AutoDesk, Capvidia, CT Core Technology, Dassault Systemes, DataKit, ITI TranscenData, Kubotek, LKsoft, PTC, Siemens, TechSoft 3D, Theorem Solutions, Vistagy
- JT, 3DPDF, 3DXML, CAP-XML sponsors are active members
- Bi-annual rounds of testing of CAD data exchange
  - Cooperate on implementing STEP
  - Feedback to STEP developers
  - Accelerate translator development
  - Promote interoperability
  - Scope is AP203, AP214, AP242
  - Capability & Validation



Semantic PMI Representation Test Model

CAX-IF Benefits

- Individual results covered by non-disclosure
  - Publish only aggregate results
- Test Suites
  - Instructions on building test models
  - Test, production models in file repository (STEP & native)
- Draft Recommended Practices
  - Model Styling & Organization
  - User Defined Attributes
  - External References
  - PMI
  - Tessellation
  - STEP File Compression
- LOTAR provides requirements and test models
- 3D PDF Generator

3D Tessellated Geometry Synthetic Test Model

CAX-IF Implementation Coverage Matrix

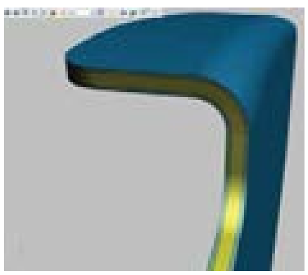
- Purpose is to coordinate vendor testing
  - Organized by major sections of Recommended Practices
- Self-reported Vendor Status
  - Categories: Production, Customer Tests, Development, Future Plans, Not Supported
    (Only Production status made public)
  - Can compare implementations
- Total of 6 Vendors testing 242 implementations
  - Sufficient to have schema and recommended practices

Public Implementation Coverage Example (CATIA V6)

Recommended Practices Functionality	AP203 E2 Import	AP203 E2 Export	AP214 IS (2001) Import	AP214 IS (2001) Export	AP214 E3 (2010) Import	AP214 E3 (2010) Export	AP242 Import	AP242 Export
Geometry								
Wireframe	X	X	X	X	X	X	X	X
Geom. Bounded Surface Model	X	X	X	X	X	X	X	X
BREP Solid	X	X	X	X	X	X	X	X
3D Tessellated							X	X
Assembly Structure								
Assembly Structure	X	X	X	X	X	X	X	X
Mapped_Item	X		X		X		X	
Composite Material								
Composite Material							X	X
Model Styling								
Solid Color	X	X	X	X	X	X	X	X
Face Color	X	X	X	X	X	X	X	X
Overriding Face Color	X	X	X	X	X	X	X	X
Edge / Curve Color	X	X	X	X	X	X	X	X

Composites

- Composite meta-data
  - Ply orientation angle and thickness
  - Material specification
- Shape
  - 2 ½ D wireframe and surfaces
  - Explicit solids
  - New tessellated geometry
- Going forward in AP242 and AP209



Composite Plies & Core Structure

AP209ed2 Multidisciplinary Analysis and Design

- Combines CAD, CAE, PDM capabilities
  - Superset of AP203ed2
  - Finite Element Analysis (FEA)
  - Computational Fluid Dynamics (CFD)
  - General numerical analysis
  - Shares base analysis models with AP233 Systems Engineering
- Developing binary format
  - Based on open source HDF5 toolkit
  - New ISO 10303-26 (part26)
- New API specification
  - BOM to ARM to AIM mapping
  - Web services implementation

Publicly sharable Finite Element Model for testing

Simulation Data Management (SDM)

- SimPDM project of ProSTEP iViP
  - Business process diagrams
  - Business process between SDM, Multi-Body, FEM, CFD, PDM
  - Not an interchange data format, it is a metadata model
- CAE Services project of ProSTEP iViP
  - Successor to Collaborative CAD/CAE Integration (C3I)
    - Successor to SimPDM
    - XML schemas and WSDL
    - Mapping to AP209 entities
- SimDM project of PDES Inc.
  - Uses AP209ed2 and 242-style Business Object Model
- CRESCENDO project of EU
  - Based on EU VIVACE, AP233/239 and PLCSlib
  - Behavioural Digital Aircraft (BDA) Model …

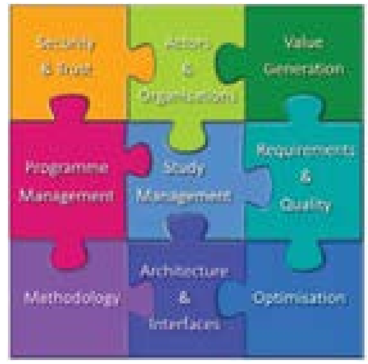
Behavioural Digital Aircraft (BDA) Model

- BDA Business Object Model defines common language exposed as web services based on 233/239
- BDA PLCSlib DEX's to be publicly released soon
  - Many base PLCS templates already available as OASIS templates
  - Not specific to aircraft, can be used for other types of products
- Web services to create, update, read and search data
  - WSDL interfaces implemented against
    - Share-a-space collaboration hub
    - Clients: MSC SimManager/SimXpert, Siemens TeamCenter/NX, Scilab, Proosis, Dassault CATIA/Enovia/iSight/Dymola, Altair/Optistruct

Benefits of PLCSlib

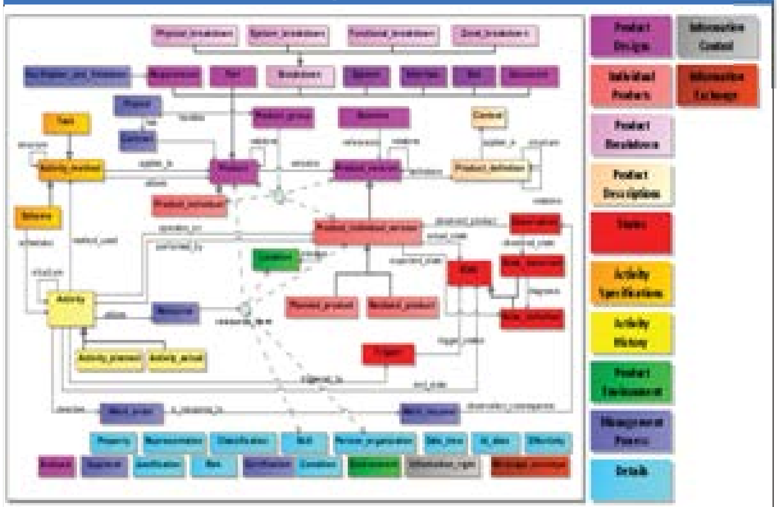
- New DEX development environment
  - Recommended by OASIS PLCS Technical Committee on all new DEX development
  - Replaces DEXlib and based on AP239ed2 International Standard (IS)
  - Generate DEX XML schema from SysML model
  - Reference data in semantic web technology (OWL2 DL)
  - Uses new templates (due to AP239ed2 and other lessons learned)
- Benefits
  - Can transform data for legacy DEX to new DEX's (no DEX transform)
  - Re-use DEXlib business information requirements/entity mapping
  - Faster DEX development (SysML IDE & encapsulation/abstraction)
  - SysML integration to Enterprise Architecture and Systems Engineering
  - Smaller file sizes and schemas
  - Better re-use and fewer base templates
  - Better quality due to built-in object and type checking
  - Software code and Web service generation

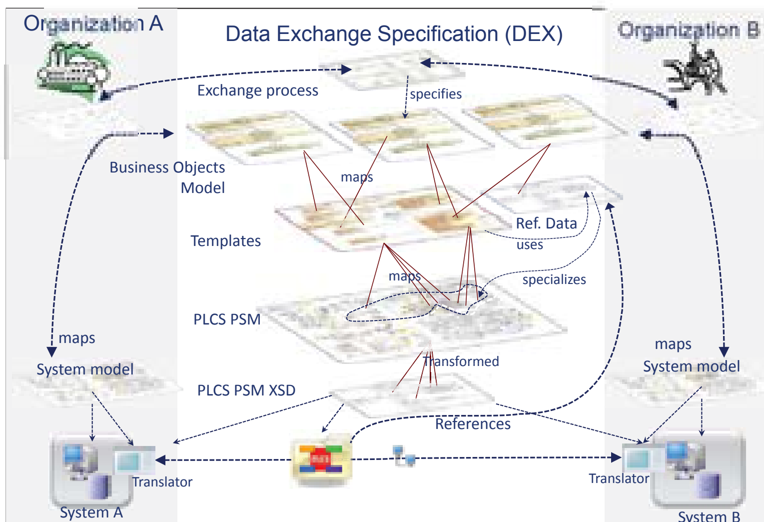
Business Object Model : BDA Dataset coverage



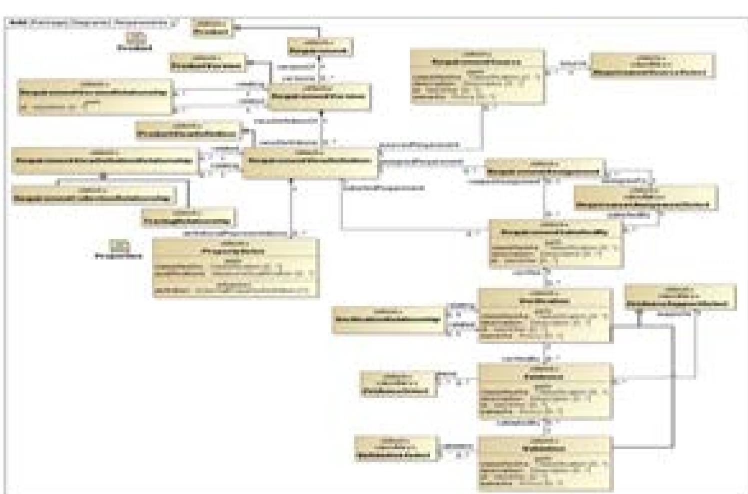
Rich model designed to enable traceability from customer expectations through to certification

AP239 ed2 PLCS Concept Model





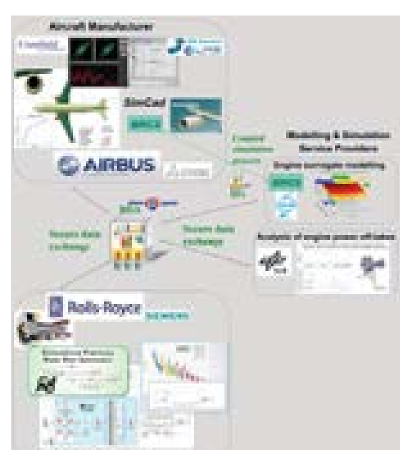
SysML Block Definition Diagram of PLCS Requirements



A CRESCENDO example (simplified)

A typical example case in CRESCENDO:

- Airbus (France and UK) start to develop a new plane based on an analysis of customer expectations leading to requirements
- Cranfield (UK) are asked by Airbus to develop engine properties to match the requirements
- DLR analyse power off-takes
- The requirements and engine properties are passed by Airbus to Rolls Royce (D and UK) to propose a type of engine with more properties and requirements for which RR then simulate
- The results of the simulation are passed to NLR (Netherlands) who produce a "surrogate model" which is passed back to RR and then made available to Airbus
- Iterate taking into account thermal, noise, pylon structures,…



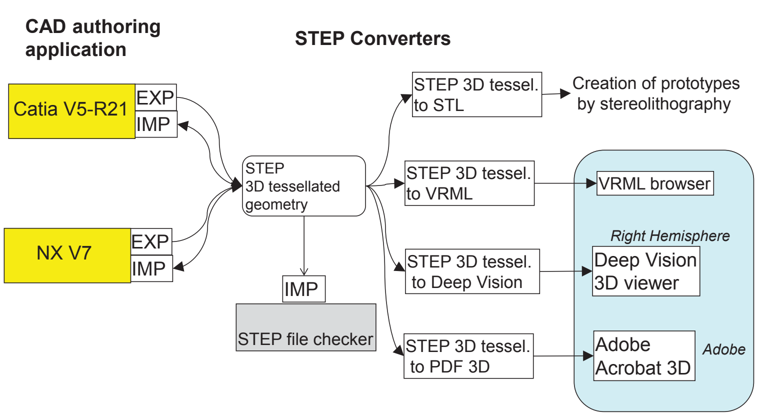
Multiple Visualization Formats

- New LOTAR visualization team
  - Provide requirements to other consortiums
  - Interoperability testing with 3D tessellation in STEP
- JT and 3D PDF working on PMI
- COLLADA from Khronos Group
  - Harvesting by ISO TC184/SC4 like JT
  - XML schema with an extension method
  - Open source toolkits available
  - Used in Digital Content Creation industry
    - CGI, gaming, training …
  - New version includes BREP, kinematics (little support yet)
  - Khronos also provides WebGL (3D model in browser)
  - Open source for COLLADA to WebGL (three.js, scene.js)

3D CAD in a Web Browser

- WebGL in HTML5
  - Embedded in most browsers, or plug-in to Internet Explorer
  - Runs on desktop and Android, RIM mobile browsers (not iOS)
  - Uses GPU for 3D acceleration
- Examples using WebGL
  - PythonOCC – STEP through OpenCascade to browser
  - Sketchfab – publishing system from CAD to web pages
  - Tinkercad – parametric 3D CAD in browser and STL interface
  - 3DTin – modeller with STL, OBJ, DAE (COLLADA) export
  - ShapeSmith – parametric NURBS open source
  - Sunglass.io – collab. viewer, parts/assemblies, CAD formats and plug-ins
- X3D plug-in for browsers
  - Collaborating with COLLADA and WebGL teams

Tessellated Geometry Interoperability Testing



PLCS and Logistics

- ASD/AIA Integrated Logistics Support S-series
  - SX000i Guide for Use of S-series: writing chapters
  - S2000M Material Management: issue 5.0 on May 3
  - S3000L Logistics Support Analysis: issue 1.1 Q1 2013
  - S4000M Scheduled Maintenance: working on issue 1.0
  - S5000F Operational & Maintenance Feedback: early draft handbook, data
  - S6000T Training Needs Analysis, TBD
  - S9000D Dictionary: issue 1.0 under development
- GEIA-0007 Logistics Product Data
  - Some DEXlib DEX's developed
  - Handbook Rev B Ballot Draft released August 20
  - Draft MIL-HDBK-502A Acquisition Logistics on Oct. 1
- Other MODs developing PLCSlib DEXs
  - France, Norway, Sweden, UK, USMC/NATO

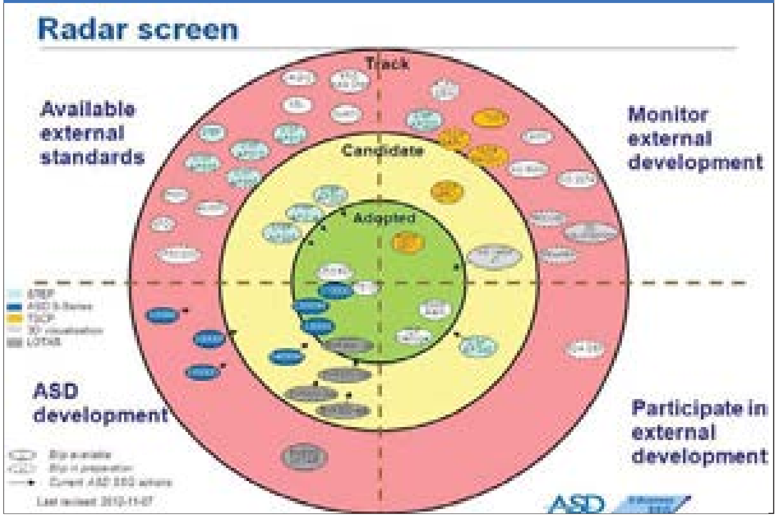
Convergence on Maintenance Feedback

- Spec 2000 from Airlines for America (A4A)
  (A4A formerly known as Air Transport Association (ATA))
  - E-business Specification for Material Management
  - For Maintenance, Repair, Operation (MRO) of civil aircraft
  - Strongly recommended by airframers in procurement
  - Chapter 11 Reliability Data Collection/Exchange
    - Eg. LRU Unscheduled Removal Record
  - Chapter 13 Performance Metrics Standards
    - Eg. To compute MTBF
- ASD Strategic Standarization Group (SSG) Plan
  - Analyze Spec 2000 and prepare adjustment proposals to A4A to fit with ASD S5000F requirements
- Challenge: Input to ASD indicates that A4A is not open to adoption of AIA/ASD S-series standards

Transglobal Secure Collaboration Program (TSCP)

- Members: MoD's, DoD, and A&D contractors
- Secure E-mail Specification v1 (SE v1)
  - Check sender/receiver for EAR and ITAR rules
  - PKI certificates for digital signature and encryption
  - Certificate Authority and cross-certification
- Identity Federation v1 Assertion Profile (IdF v1)
  - Security Assertion Mark-up Language (SAML) profile for A&D
  - Attributes also passed through WS-Fed Protocol
- Communicating with OASIS PLCS TC on Information Rights Management

Standards Radar Chart by ASD



STEPcode Open Source

- Based on legacy NIST STEP Class Library
  - BRL-CAD Open Source Reference Implementation
  - BRL-CAD used Coverity for static code analysis to find and fix defects and security vulnerabilities
- Current STEPcode functions
  - Generates p22 SDAI class library in p23 C++ binding
  - Compiles p21read/write executable
  - Works on major EXPRESS schemas and p21 files
- www.stepcode.org
  - scl-dev Google group discussions on STEP
  - Used by SCView: EXPRESS-G, tree & text viewer
  - Github: Notepad++ plug-in for EXPRESS schemas

Conclusions

- Many complementary interoperability standards for models across domains and the life cycle
  - Need to define interfaces (map overlaps and fill gaps)
  - Need to portfolio manage collections (like LOTAR & ASD SSG)
- Technology is available, but needs investment
  - Standards development infrastructure (eg. STEPmod)
  - Share implementer forum resources and best practices
  - Tighten implement/test/feedback/modify cycle like CAX-IF
  - Need open source reference implementations
  - Sharing best practices (Validation, UIDs, Testing …)

LOCKHEED MARTIN ENGINEERING

Evolving Lockheed Martin's Engineering Practices Through the Creation of a *Model-centric Digital Tapestry*

Tom Hannon
Advanced Engineering Practices
Lockheed Martin Corporation

The New Reality – Affordability and Resilience

Systems 2020 Vision

- Adversary can use commercial technologies and new tactics to rapidly alter the threat to US forces
- DoD engineering, and business processes not structured for adaptability
- New research, tools, pilot efforts needed to determine best methods for building adaptable defense systems
- **Need <u>faster delivery</u> of <u>adaptable</u> systems that are <u>trusted</u>, <u>assured</u>, <u>reliable</u> and <u>interoperable</u>**

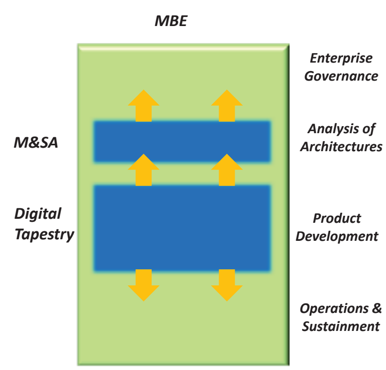
Existing Gaps and Critical Needs

- Gap: Lack of a Conceptual Design Environment
- Gap: Lack of tools to integrate system modeling capabilities across domains
- Gap: Lack of open, virtual and realistic environment for validation and producibility analysis
- **Need an <u>integrated</u> (i.e. cross discipline) framework for concept, <u>design and analysis</u> of systems based on standards, open architecture and existing COTS tool sets**

Model-Centric Digital Tapestry: Lockheed Martin Model-Based Enterprise

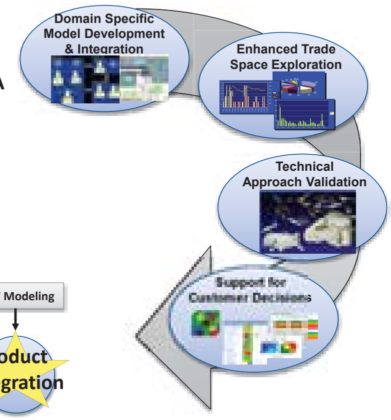
Model Centric Digital Tapestry

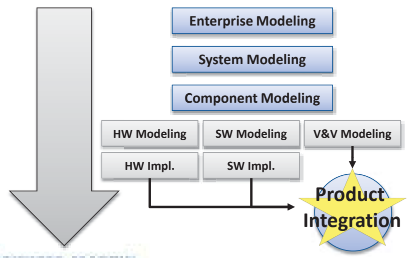
- An aligning vision, framework and strategy for integrated business, engineering and manufacturing supported largely by Model Based Systems Development.
- Focused on linking the architectural framework with the Model-based integrations of design, analysis, cost prediction, technology management and production methods
- Enables Performance Prediction with Execution Prediction and O&S Prediction
- An enabler to meet the challenge of the Systems 2020 vision and Resilient Systems for adaptability, affordability and rapid design.



Enabling our Engineers

- Expertise Utilizing Model Based Practices And Integrated Tool Suites Allows More Variables And Trade Permutations To Optimize A Design And Find The Best Value Solution Faster





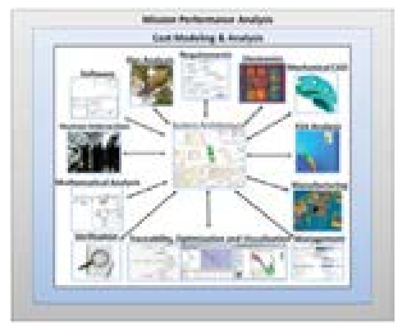
Existing Modeling Activities

- Most engineers leverage *focused* modeling activities across various disciplines.
- Capability to support integration across discipline lines tends to be limited or missing.
- Existing integrations tend to be "point to point"

Architecture Cost CAD Performance Manufacturing

SysML: An Enabler for the Digital Tapestry

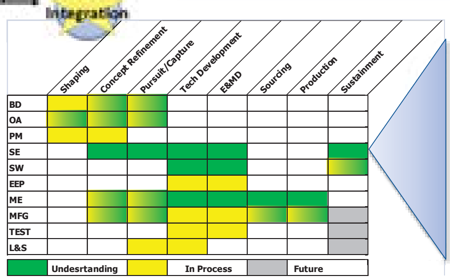
- A well defined System Architecture Model (SAM) is the underlying structure connecting threads of digital information together.
- The SAM helps link requirements to logical and behavioral design.
- Requirements can be fed into increasingly detailed levels of domain specific modeling.
- By viewing the SAM as the hub of the digital tapestry, an integration pattern emerges enabling cross-domain connectivity with a minimal set of required integrations.



Lockheed Martin Model Based Portfolio

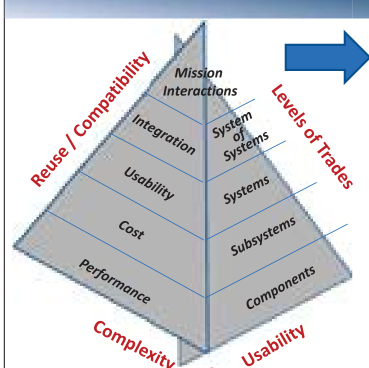
Today's Hard Problems are *System Level* Problems. Therefore Lockheed Martin's Model Based Effort is Grounded with a Solid Model-based Systems Engineering and Architecture Portfolio

LM's Model-based Strategy is Focused on Pulling Model-based Digital Threads from Concept Development through Design to Test, Production and Sustainment



Partitioned Across Multiple Programs and Pilots

Expand, Accelerate and Validate Trades



Customer Business Climate Demands More Levels and Complexity of Trades to build Compatible Affordable Useable Solutions

Calls for and Integrated Digital Analysis Thread for Performance, Cost, Usability and Compatibility Accelerates Trade Analysis

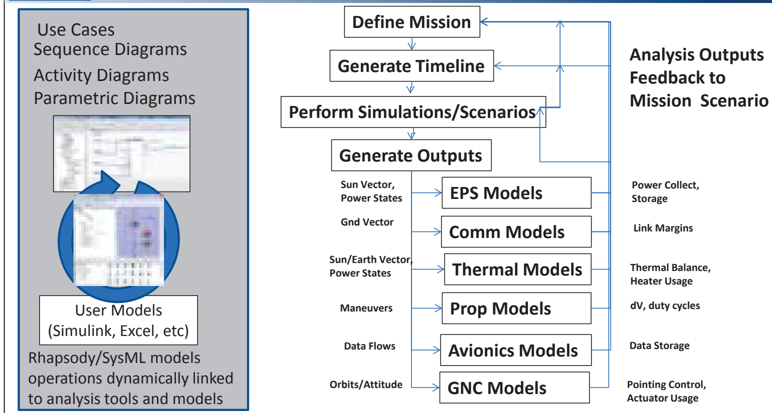
- ✓*Model Based*
- ✓*Standards Based*
- ✓*Integrated / Compatible Tools*
- ✓*Technical Progress Validation*
- ✓*Mission Performance and Force Compatibility*
- ✓*Customer Inclusion*

Key Components for Enhanced Trades

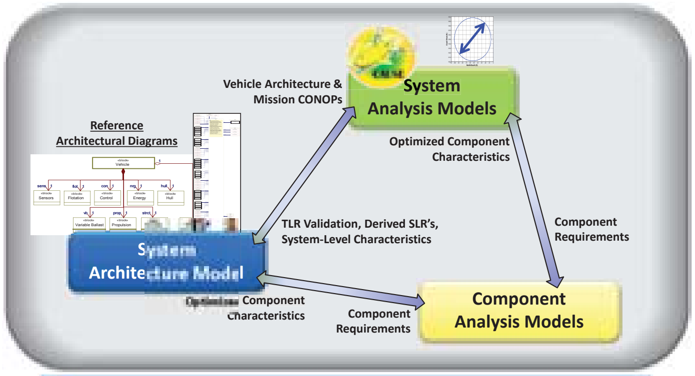
- Leveraging system architecture models and integrated domain models to trace requirements to product design
- Integrating analysis models and tools into a common model-driven framework to drive performance, cost, and schedule analyses
- Integrated visualization and dashboards to track performance, completeness and customer value of the solution space
- Utilize subject matter expertise to develop standardized distributed analyses

Providing Glue Between Architecture, Cost, Performance Analysis and Overall Value Assessment

Integrated DRM Process

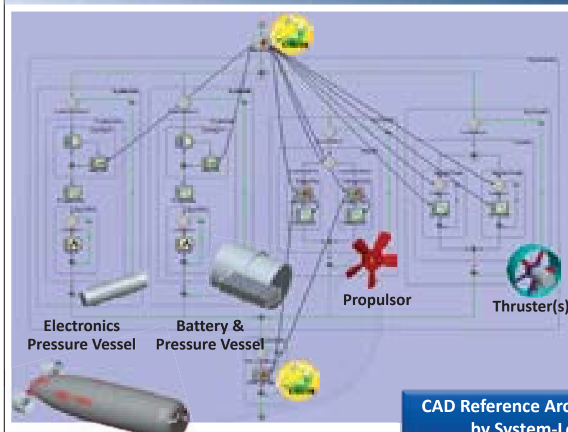


Integrated Analytical Models



Integrates System Engineering and Analysis Capabilities to Provide Framework for Early Business Shaping

UUV Reference Component Model Suite



Component Requirements Are Based on System-Level Allocation

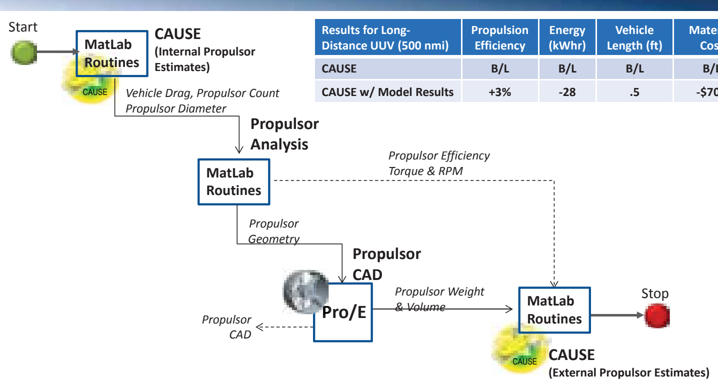
Component Analysis Models Provide Higher-Fidelity Sizing & Design

Second CAUSE Run Captures Higher Fidelity Estimates & Identifies System-Level Impacts

CAD Reference Architecture is Driven by System-Level Analysis

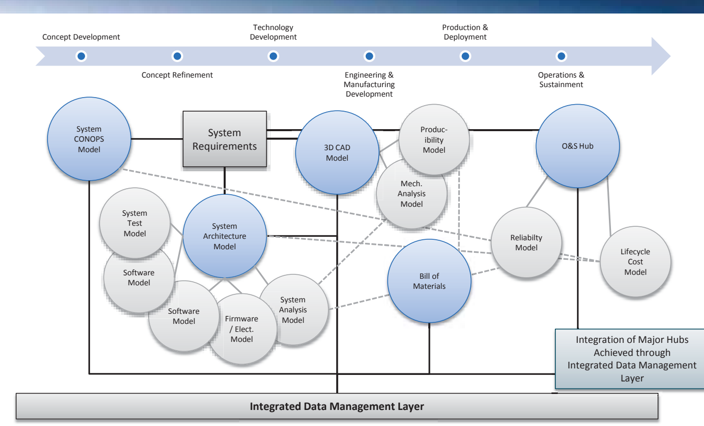
Example: Integrated Propulsor Analysis

Results for Long-Distance UUV (500 nmi)	Propulsion Efficiency	Energy (kWhr)	Vehicle Length (ft)	Material Cost
CAUSE	B/L	B/L	B/L	B/L
CAUSE w/ Model Results	+3%	-28	.5	-$70K

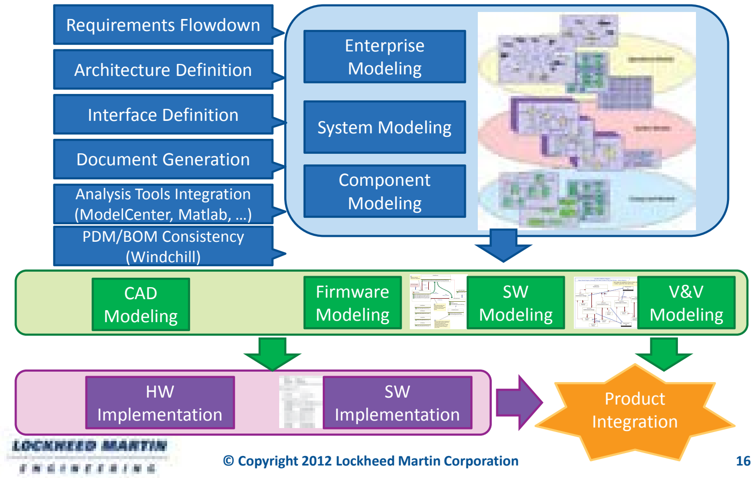


Propeller Models Generate More Accurate Vehicle Assessment In Addition to Component CAD Suitable for Vehicle Arrangements and Future Analyses

Integration Clusters (Technical "How")



Model-based Program Execution



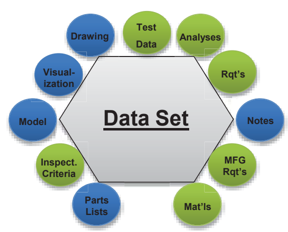
Vision: Single Source Generative Practices

- Generating code, interfaces, test cases, documentation, and more from models and higher level languages
- Many programs at LM and across industry leverage generative coding for targeted problems
- Core to 2013 MBSD are refining the paths from UML, SysML and Simulink to software, firmware and interfaces

Not Just a Model but a Product Data Set

A Product Data Set Contains Artifacts That Define A Product…

- 3D Model
- Specifications
- Notes
- Metadata or Attributes
- Bill Of Material
- Design Requirements
- Other Product Descriptive Info

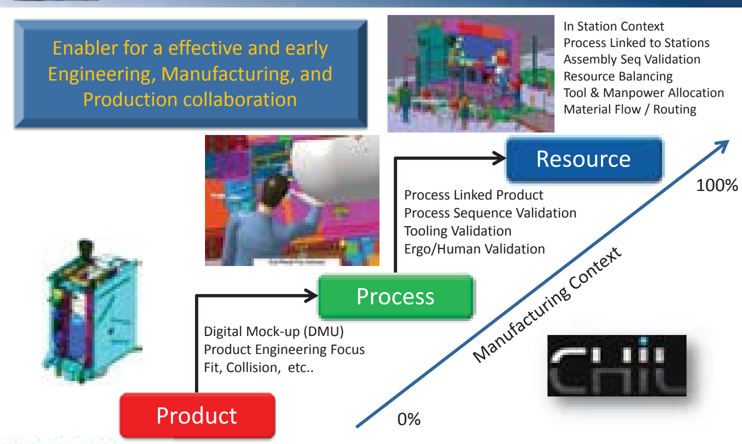


The Entire Data Set Must Be Managed

- Creation & Control
- Association To Design

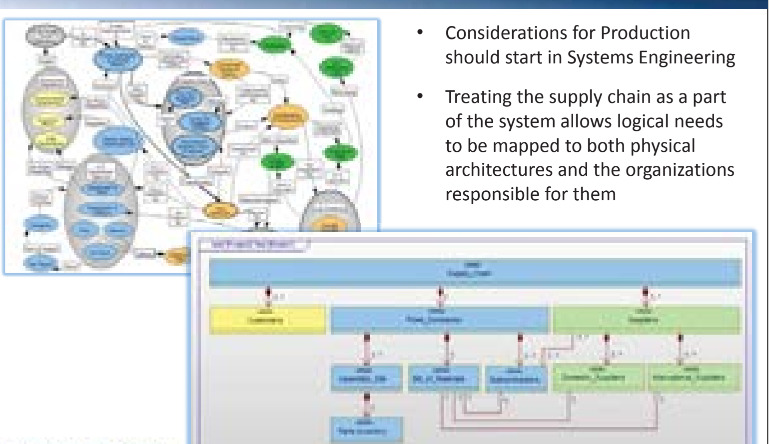
SSC's Future in Virtual Manufacturing
Virtual Creation before Physical Creation

Enabler for a effective and early Engineering, Manufacturing, and Production collaboration



Understanding and Managing the Supply Chain

- Considerations for Production should start in Systems Engineering
- Treating the supply chain as a part of the system allows logical needs to be mapped to both physical architectures and the organizations responsible for them



Digital Tapestry Highlights

- AS Enabler:
  - Moving Information And Decisions Earlier
  - Horizontal Agility Across Functions And Disciplines
  - Creating Business Tools
  - Connecting Mission To Solution Details
  - Enhancing The Trade Space
- As Core Model Centric Approach
  - Single Source of Truth
  - Generate From Common Sources
  - Clarity of Design and Traceability
  - Technical and Performance Progress

IBIF Projects and Business Case Analyses

Denise Duncan, Cindy Flint
13 December 2012
MBE Summit, NIST

LMI

IBIF projects

- The Industrial Base Innovation Fund (IBIF)* program recently solicited proposals in the area of technical data
  - Technical Area 1: Comprehensive Technical Data Packages (TDPs) for Next Generation Business Exchanges
  - Technical Area 2: Technical Data Packages (TDP) Integration and Validation for Government Delivery
- LMI is tasked to help IBIF TDP project teams develop high-level BCAs

* Part of the OSD Defense-Wide Manufacturing Science and Technology (DMS&T) program

LMI

LMI's role in IBIF projects

- LMI is tasked to help IBIF project teams develop high-level business cases
  - Collaboratively define metrics with project teams
- We are currently completing a 2012 task – white paper on the Case for MBE
  - Includes case studies from projects completed by the MBE community
  - As much as possible, IBIF metrics should be similar to earlier studies

LMI

What is a business case?

- Can depend on who you are talking to
  - BCA, CBA, AOA, ROI, Cost-Benefit Ratio etc.
- And what they need it for
  - What have we gotten for the money?
  - Milestone decisions
  - Justify future/ongoing investment
  - Prioritize investments
  - Answer audit inquiries
- Business case templates vary
  - By agency or Service
  - By investment dollar thresholds
  - By investment type, e.g. major system, R&D, IT, etc.
- However, there are standard steps in developing any business case

LMI

Business Case Steps

- Step 1: Define the "As Is" Case
  - Define the current process, technology, system, and/or standards being addressed .
  - What problem or inefficiency is resulting from the status quo?
  - Benchmark the current process, technology, system and/or specification (e.g. resources, cycle time, quality, maintenance, etc).
  - To the extent possible, quantify the status quo.

LMI

Business Case Steps (continued)

- Step 2: Alternative(s)
  - Define the alternate process, technology, system, and/or standards being studied.
  - How does this alternative address the problem or inefficiency described in the "As Is" case?
  - State the proposed benefits of the alternative. When the benefit will be achieved, who will benefit, certainty of the benefit.
  - Is there industry and government support for the alternative and why?
  - What, if any, impediments to implementing the alternative have you identified.
  - To the extent possible, quantify the alternative.

LMI

Business Case Steps (continued)

- Step 3: Supporting Information
  - State any assumptions associated with the analysis.
  - Document any policies, regulations, and/or standard operating procedures pertinent to the problem and resolution.
  - For benefits that are qualitative in nature, document the benefit giving a description of the benefit and naming the stakeholder.

LMI

Business Case Steps (continued)

- Step 4: Economic Analysis
  - An economic analysis is used to compare the status quo to the alternatives. Several methods can be used: NPV, statistical modeling, cost/benefit ratio, etc.
  - The type of project and/or stage of the project may dictate the level of detail needed for the analysis.
  - OMB circular A-94 "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs": *http://www.whitehouse.gov/omb/circulars/a094/a094.html#5.*

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